SCIENCE TEACHER'S WORLD

Teacher's edition of Science World • April 21, 1959

Science World

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Dear Teacher-Subscriber:

Mid-April may seem an odd time to be talking about next fall, but educational publishers, like teachers, must plan ahead. The opening days of school are a busy season for you; they're also busy for us because they bring a deluge of orders for SCIENCE WORLD. Therefore, we'd like to suggest that you take a minute now to make use of the tentative order card bound into this issue. If you do it now, the first issue of <u>SW</u> will be on your doorstep shortly after school opens. This will also ease our fall rush.

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Student Science Projects
Viruses: The Big Break-throughs
The Exploration of Space

Naturally, SCIENCE WORLD will also continue its wide coverage of science in many fields.

May we hear from you soon?

Sincerely yours,

Patricia Lauber

Patricia Lauber
Editor-in-Chief

STW Contributing Editors: Alexander Joseph and Zachariah Subarsky

Five tips for teaching slow learners

■ Every medical doctor sooner or later treats patients who fail to recover. Similarly, every teacher is sometimes confronted with students who fail to learn. In both cases, factors are often involved that are beyond professional control. A student, for example, may be living under home conditions the effects of which spill over to the classroom and make learning almost impossible. A student may have developed an extreme hostility to school and everything associated with it, thereby becoming refractory to any approach the teacher can make. Or a student may be mentally retarded and may require the services of a specially trained teacher.

This article does not deal with such extreme deviates. It does deal with the student who, while slow, is nevertheless a learner. To describe such a student is to put one's finger on implications for teaching him.

Characteristics of the slow learner. The slow learner is usually retarded in basic skills, notably the ability to get information from the printed page, the ability to express himself clearly in speech and in writing, and the ability to perceive quantitative relationships. He has difficulty in retaining and recalling information, in drawing generalizations from particulars, in applying generalizations to particulars, and in abstract thinking. Often, but not always, he comes from a home that is culturally impoverished — a home where there are few, if any, books and where siblings and parents have little interest in learning and offer little encouragement to learning. The perceptive teacher will find that the slow learner usually bears many deep psychological scars of disapprobation and condemnation.

It must be pointed out that not every so-called slow learner is in such a sorry state. In fact, one or two quite-average learners in a very bright class may find themselves in the position of "slow learners" in relation to their classmates.

Implications for science teaching. Most of the suggestions below apply, in principle, to the teaching of science to students of every level of ability. But to the slow learner, their application is crucial.

1. *Provide an adequate background of experience for reading.* The problem of poor reading ability is not solved just by providing "simple," lower-grade reading material. In fact, the slow learner may deeply resent being fed mental baby food, so to speak. Do provide reading material on his maturity level. But before you assign any such reading, be sure you have also provided direct, first-hand experience — visual, tactile, and auditory — that will give meaning to the words, sentences, and paragraphs he is about to read. For example, if the reading material is on how the telephone works, be sure the student has seen and touched a diaphragm, has seen carbon particles and has witnessed them modifying a current in an electric circuit, has seen an electromagnet and has witnessed how the strength of an electromagnet is modified by variations in the current flowing through it.

Anticipate vocabulary difficulties and teach the meaning of words the student will encounter. It almost amounts to this: the reader should already know what he is reading about.

2. *Use "props" to aid imagination.* Motion pictures and animations can be used to help the student visualize dynamic events, such as a cell dividing, a string vibrating, a piston moving. But do not merely show diagrams; whenever possible develop them. For example, when teaching the water cycle, the course of blood through the heart, land and sea breezes, and the like, develop the diagrams on the blackboard by way of a series of questions. Then call on students, in turn, to explain the diagram as a whole. On the other hand, when you use a chart, orient the students to the chart as a whole before you begin discussing any part. Such orientation might begin with a question like this: what did the artist who made this chart have in mind to show us?

3. *Vary student activities within the class period.* In every lesson, provide something for the student to *do*. The activity should be individualized, definite, and capable of being carried to completion. It might take the form of writing specific notes, copying a diagram that has been developed on the blackboard, taking a short test, or engaging in a short period of drill. The span of attention of the very slow learner seldom exceeds fifteen minutes. Intervals of activity, such as those mentioned, tend to enhance learning during intervals of direct teaching.

4. *Tactfully involve the slow learner in the class recitation.* This suggestion applies to slow learners who are in a class of intellectually heterogeneous students. In such a class, the teacher tends to call on those who wave their hands most vigorously — the bright students. If the slow learner is called on, he usually doesn't know the answer.

It is good practice, after you have received a satisfactory answer from a bright student, to call on several "slow" students, in turn, to repeat the answer. This practice provides useful drill for the entire class. In the course of a discussion, when a point is clinched, put these questions to the class: What would you suggest we record in our notebooks? How shall we word it? Through the interplay of minds of several bright students, a good "final wording" may be elicited. At this point, call on one or two slow students to repeat the final statement. Then have everybody write the statement in his notebook.

5. *Provide opportunities for successful accomplishment.* All students thrive on success and the recognition of success. The slow learner is starved for these. Carry out adequate drill and review before you give a test. When you do test, be sure to include at least some questions with which the slow learner can successfully cope. Rec

[*Continued on p. 6-T*]

MEMO

To: Science teachers

Subject: Ways to use this issue of SCIENCE WORLD in the classroom

Polaris: flying torpedo

GENERAL SCIENCE AND SCIENCE CLUB TOPIC: rocketry

Jules Bergman describes the development and structure of a Navy missile that will be launched from under the water. This article will fire the imagination and whet the appetite of the young rocketeers in your science class or science club. Here are some questions that may be used to arouse curiosity:

1. Why is a solid fuel better than a liquid fuel for use in rockets that are to be fired from ships at sea?
2. What problem of solid fuels had to be overcome to make them suitable for missiles fired from ships?
3. What is the "secret" of a successful solid fuel?
4. In the development of Polaris, why did it have to be "aged, frozen, heated, and vibrated"?
5. Why is Polaris's shape like that of a bowling pin or a soft-drink bottle?
6. How is Polaris steered?

The shadowy figure of Roger Bacon

SCIENCE CLASS TOPIC: history of science
SCIENCE CLUB TOPIC: Roger Bacon, pioneer in scientific thinking

One of the objectives of education is to awaken in young people an appreciation of their cultural inheritance. Among the things students are all too prone to take for granted, together with freedom and democracy, are the social traditions that underlie the scientific enterprise. The author calls attention to Roger Bacon, the man who pioneered in freeing the human mind from the slavery to "authority," "custom," "the mob," and "the pedant." Bacon pointed the way to experimentation as a trustworthy method of obtaining answers from nature.

In conjunction with this article, the teacher might assign reports on the prevailing ideas about:

1. The earth and solar system before Copernicus.
2. The origin of flies before Redi.
3. The vacuum before Torricelli.
4. The heart before Harvey.
5. The origin of germs before Pasteur.

The subtle storm

PHYSICS TOPICS: nucleonics, electromagnetic induction, short-wave radio transmission, terrestrial magnetism, heliography
GENERAL SCIENCE TOPICS: weather cycle, sunspots, solar flares and auroras, the compass, magnetism, radioactivity
EARTH SCIENCE TOPICS: solar system, terrestrial magnetism, weather cycle

The demonstration of iron filings arranging themselves in a magnetic field seldom fails to create wonder. The same holds true for the impression of "fluidity" that is given when like poles of magnets are brought together. John Brooks' article enables you to associate even this simple demonstration with a phenomenon so vast and involving energies of such magnitude as to dwarf the most violent *earthbound* storm.

Magnify the tiny magnet to a magnet the size of the earth, sprinkle it with electrons that pour from cataclysmic flares on the sun — and things happen! Everything electrical and magnetic on the earth is affected — compass needles go astray and lead ships off their courses, power transmission lines go dead, radio messages become unintelligible, and the night sky is hung with streaming, glowing auroras.

Mr. Brooks describes such an electromagnetic storm as seen through the eyes and minds of a world-wide team of IGY scientists, and he describes it in a way that has the reader experiencing the excitement, wonder, and awe of an electromagnetic storm.

Class discussion

1. How does a solar flare show up on a monochromatic heliograph?
2. When picked up by high-frequency receivers, what do radio noises from solar flares sound like?
3. Why is it difficult to forecast magnetic storms?
4. What was John H. Nelson's method for predicting magnetic storms?
5. Since magnetic storms are so violent, why did they go undetected until recent years?
6. What are the effects of magnetic storms on power-transmission lines, compasses, and telegraph communication?
7. Through what geographical areas do the centers of northern auroras and southern auroras run?

Class demonstrations

1. Show the glowing effect of a stream of electrons in a partially evacuated Crookes tube.

2. Using a Crookes tube or cathode-ray tube as a source of weak X rays (or using a source of atomic radiation), demonstrate the ionization of air by the discharge of an electroscope.

From chemistry set to chemical engineer

CHEMISTRY TOPICS: synthetic fibers and plastics, career guidance
GENERAL SCIENCE TOPIC: career guidance

Edd Wall's life story can be used in a career-guidance unit at the end of the chemistry or the general science course. It will give a youngster a realistic idea of the abilities, qualities, and training that are required for a successful career as a chemical engineer. The student will also get some conception of the kinds of work that a chemical engineer does. Since the story begins with young Edd being fascinated by a chemistry set, the student-reader will readily identify himself with Edd.

Class discussion

1. What are some advantages of going to a junior college (assuming that the college is a good one)?
2. Why are non-science subjects and extracurricular activities important in the training of an engineer?
3. How might summer vacations contribute to one's training and choice of a life work?
4. Some of the most important things one learns in an engineering school have nothing to do with science. What are some of these?
5. What are some of the kinds of work that a chemical engineer does?

They hunt the smallest game

BIOLOGY TOPICS: virology, ecology, bird migration, serology, genetics
GENERAL SCIENCE TOPIC: fighting infectious diseases

This is the concluding portion of Murray Morgan's account of the work of Causey and Causey, that remarkable husband-and-wife team who roam the jungles of South America, collecting viruses from the blood of man, monkeys, juparas, anteaters, sloths, opossums, rats, bats, juritis, chickens, lizards, chameleons, mosquitoes, and a variety of wild birds. The jungle fauna constitute a potential pool of virus diseases that may be carried by man-made or by natural "vehicles" to kindle epidemics among susceptible human populations. In a rustic jungle laboratory and with crude, improvised equipment, the collected viruses are cultured and assayed in the brains of mice. They are then sent for identification to the laboratory of The Rockefeller Institute for Medical Research in New York City.

But the Drs. Causey are more than mere collectors; they seek information on how a given virus spreads geographically. And this leads them to engage in strange occupations. For example, they place monkeys in cages suspended between the jungle floor and its ceiling. Also, they catch mosquitoes, color them with gold leaf, and release them for later capture. Altogether, Mr. Morgan's detailed story is indeed "stranger than fiction." And it can serve the biology teacher as a source of enrichment in the teaching of a wide variety of topics (see above) in the biology syllabus.

Teaching suggestion

As an assignment, have the article read by several members of the class, each member to report to the class on one of the following questions:

1. How did the Drs. Causey become involved in the kind of work they are doing?
2. How did the Causeys become interested in a problem in genetics?
3. How did the male Dr. Causey trace the movement of jungle fever?
4. How does the Causey jungle laboratory affect international relations?
5. Why do students of yellow fever study bird migration?

Science teacher's question box

Have any mutations ever been produced in protozoa by subjecting them to X rays? — T. R., Schenectady, N. Y.

Dr. Ralph Wichterman of Temple University has subjected paramecia to X rays and has produced mutants without micro-nuclei, mutants with a reduced reproduction rate, and mutants with reduced body size.

What has happened to the flurry of rain-making activity of a few years back? Has it turned out to be a failure? — R. R. B., Portland, Ore.

Dr. Henry G. Houghton, head of the department of meteorology at MIT, states (*Science*, February 6, 1959): "One can be quite confident that the ultimate success of methods for the artificial release and control of precipitation will depend on the acquisition of much more complete basic knowledge of the ways in which nature produces rain and snow. Present attempts at rain-making are often uncomfortably close to shooting in the dark."

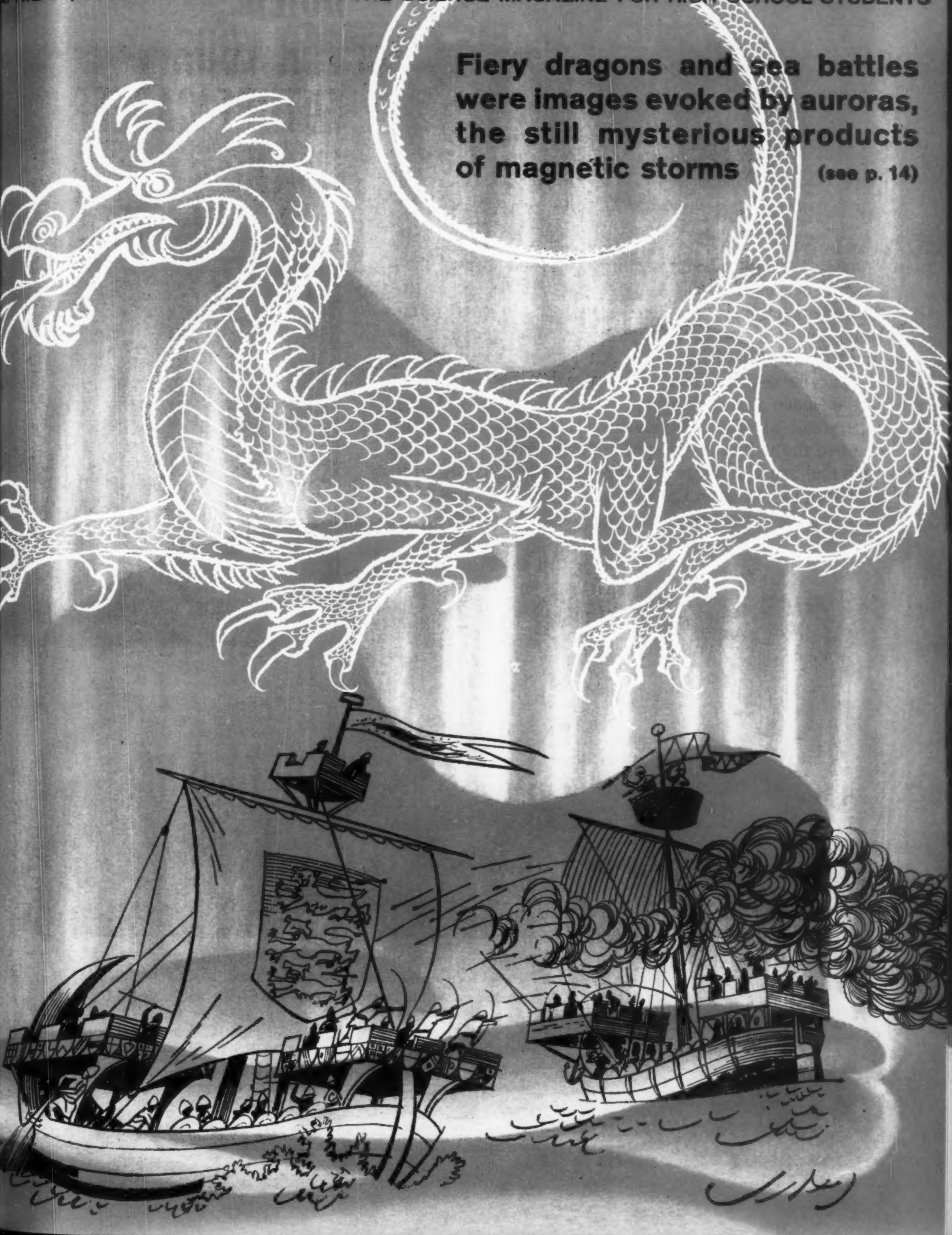
Questions from teachers will be answered here, as space permits. Send questions to: Science Teacher's Question Box, Science Teacher's World, 575 Madison Avenue, New York 22, N. Y. We regret that questions cannot be answered by mail.

SCIENCE WORLD

APRIL 21, 1959

THE SCIENCE MAGAZINE FOR HIGH SCHOOL STUDENTS

Fiery dragons and sea battles were images evoked by auroras, the still mysterious products of magnetic storms (see p. 14)



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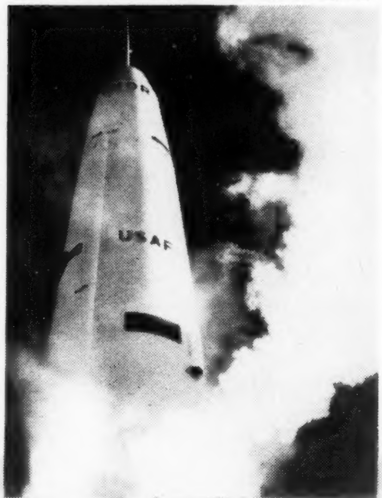

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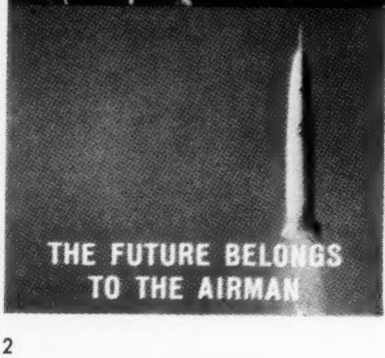

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SCIENCE WORLD

THE SCIENCE MAGAZINE FOR HIGH SCHOOL STUDENTS

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Coming in SW, May 5

Where does the United States stand with Russia in the great rocketry race? Which country will first put a man in space?

What evidence led Darwin to his theory of natural selection?

Commercial jets have been subjected to some of the most rigorous testing in aviation history. Why was this necessary?

In what ways do magnetic storms affect activities on the earth?

For answers, see next issue of *SW*.

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Features

Stranger Than Fiction

Departments

Attention, 'Asking' fans

Because of the tremendous number of requests that we receive for materials listed in "Yours for the Asking," we must make the following changes in procedure:

1. No coupons from the 1958-59 school year will be valid after June 1, 1959. All requests for material listed in "Yours for the Asking" must be mailed on or before that date. Requests received after that date cannot be fulfilled.

2. We would appreciate your asking only for materials listed during the spring semester. Many of the companies that sponsored fall materials report that they are now out of stock.

3. Please be sure your requests are mailed to the address given on the coupon. It will insure faster service for you. Remember to include your own address!

Finally, we'd like to remind you again that the only information available through SCIENCE WORLD is that published in the magazine or listed in "Yours for the Asking." Unfortunately, it is impossible to fill the many special requests that we receive.

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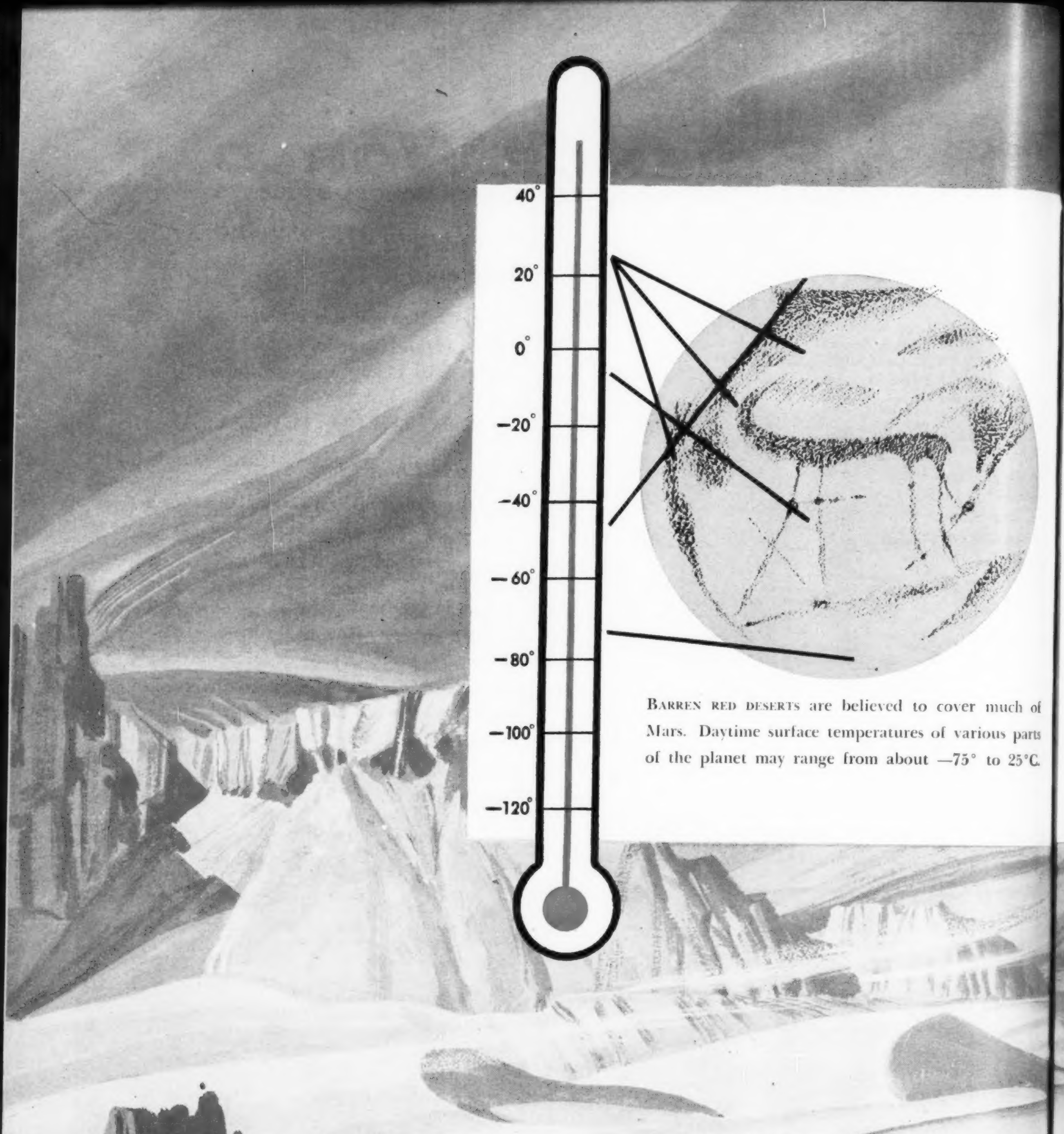


BARREN RED DESERTS are believed to cover much of Mars. Daytime surface temperatures of various parts of the planet may range from about —75° to 25°C.

Life on the red and green planet?

Scientists have long been intrigued by the possibility of life on Mars.

Now, as a space probe approaches, experiments indicate that plant life may exist there

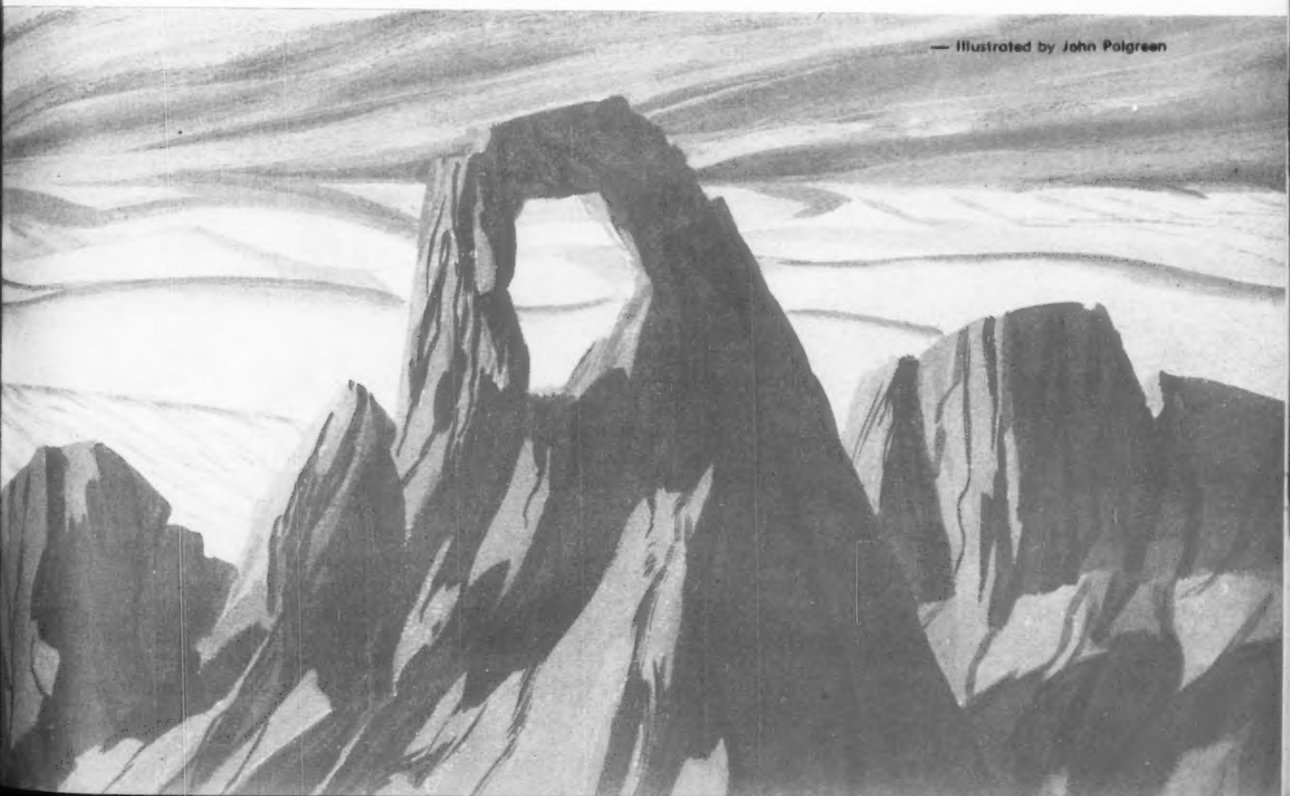
By Eliot Tozer

■ Sometime soon the United States will send a space probe to Mars. For astronomers, who have long studied our planetary neighbor with telescope, spectroscope, and polarimeter, this may well prove the most exciting rocket shoot to date. Such a probe may finally answer the question: Does life exist on Mars?

Some astrobiologists believe that it does — and this article reflects in large part their reasoning. They do not think that three-eyed monsters or "little men" cavort about the Martian plateaus. Nor do they believe that Mars is dotted with brilliant red flowers, as some science-fiction writers suggest. They do, however, think that lichens or mosses carpet Mars's equatorial plains, turning green in spring and spreading rapidly as the polar icecaps shrink.

This blanket of lichens is in itself unimportant. But it would prove that life as we know it is not a phenomenon unique to the planet Earth. And it follows that, if life exists on two planets in our tiny solar system, life probably exists on planets whirling around other stars in our galaxy — perhaps in the form of human beings.

Because the knowledge that there is life on other worlds would be of profound religious and scientific significance, astronomers for some eighty years have been speculating on whether the dark areas on Mars are vast reaches of plant life. But it was only a few months ago that scientists came up with any strong



— Illustrated by John Polgreen

evidence. Last year, an astronomer of the Lowell Observatory at Flagstaff, Arizona, made a new discovery by spectroscope (a device that breaks a ray of light into its component waves). And a few months later, a young lieutenant at the USAF School of Aviation Medicine concluded a most unusual experiment. Their explorations seem to indicate that the dark areas on the dull-red, dusty surface of Mars may indeed be living plants.

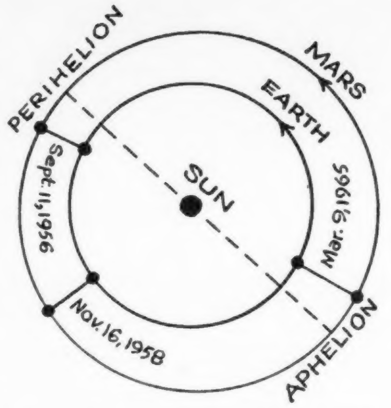
However, before looking into this new evidence, let's take a look at what is known about Mars. [EDITOR'S NOTE: figures given for Mars are not absolute and vary somewhat from source to source.]

In some ways, Mars is much like Earth. It rotates on its axis once every 24 hours, 37 minutes, so its day is about the length of ours. Since its axis is tilted at 25 degrees (Earth's at 23.5 degrees), its seasons come in Earth-like rotation.

But at perihelion (the point in its elliptical orbit closest to the sun) Mars is 129,000,000 miles from the sun. At aphelion (the point farthest away) it is 154,000,000 miles from the sun. This means that it travels much farther than Earth in one revolution (Earth's mean distance: 93,300,000 miles). And since Mars travels more slowly (at 15 miles per second as compared to Earth's 18.5 miles per second), Mars takes 687 Earth days to make one revolution. Its year is almost twice as long as ours.

Summer in the northern hemisphere (when its north pole is tilted toward the sun) happens to come when Mars is farthest from the sun. As a result, the northern summer is long (182 of our days) but cold; even at noon, the temperature just barely creeps above freezing.

Summer in the southern hemisphere, although shorter (160 of our days), is quite warm. During the day, the temperature is probably a pleasant 25°C. (77°F.). But because the atmosphere is so thin (atmospheric pressure is about one-tenth of Earth's) any heat built up during the day in the craggy Martian soil escapes rapidly — just as it filters upward from Earth's cloudless deserts. The temperature during a southern summer night on



GOOD 'LOOK' at Mars came in 1956, when it was closest to Earth and when sun, Earth, and Mars were in line.

Mars probably plunges far below freezing.

Mars, then, doesn't have much of a growing season. How about the other needs of life: good rich soil, plenty of oxygen, lots of water? The story is just about as bleak.

Mars's original hydrogen-methane atmosphere was probably converted billions of years ago to an oxygen atmosphere by the action of the sun's ultraviolet rays; but its low gravity (only 38 per cent of Earth's) let the oxygen escape. Best guess is that Mars's thin blanket of air is 98.5 per cent nitrogen; 1.2 per cent argon; 0.25 per cent carbon dioxide; and only 0.05 per cent oxygen and neon.

The soil on Mars is probably composed of aluminum-oxide and iron-oxide dust. A famous French astronomer, Audoin Dollfus, believes, after analyzing the light reflected from Mars with a polarimeter, that it is mostly limonite (a hydrated ferrous oxide). In fact, common ordinary rust may give Mars its reddish color. Other scientists think they detect a heavy concentration of felsite. In either case, it would be mighty hard for Earth-born organisms to take root and flourish there.

There's not much moisture either. There are a few clouds in the sky: blue ice clouds at altitudes of 20 miles or more; white ice clouds at four to 16 miles; and yellow dust clouds near the ground. But they probably never yield any rain.

Still, there must be some moisture in the atmosphere. How else can we explain the brilliant, snowy "icecap" that spreads out from the north pole during the northern winter? Or the south polar cap that also grows and shrinks but never quite disappears? These thin luminous caps, shown by spectrographic analysis to be frosty crystals, apparently shrink or sublime each spring and recondense each fall.

So, Mars's atmosphere is cold and almost devoid of oxygen and moisture. Could life possibly survive there?

We know that lichens — fungi and algae existing in a partnership — can live under extremely harsh conditions (*SW*, Jan. 20, 1959). Last year more than 60 species were found on a stony peak of the Sentinel Range in Antarctica by lichenologist George A. Llano. So they can live in extreme cold. In 1936, the Kellian-Feher expedition, studying the microbiology of Saharan soils, found 98 species of bacteria, 28 species of fungi, and 84 species of algae living in soils whose moisture content was below 0.5 per cent. So lichens can live in extremely dry soil.

But could they live in Mars's hostile nitrogen atmosphere? Logic says they must. How else, ask certain astronomers, can we explain the seasonal changes in the planet's dark area? In 1878, Emmanuel Liais, a French astronomer, noticed that when a polar icecap melts, releasing water, the dark areas seem to wake to life. They change from gray-green to dark green. And they spread toward the equator. Other green islands have suddenly sprung up in the midst of the ocher deserts, while still others have faded away as though covered by wind-blown dust.

Still, Mars is millions of miles away. And our atmosphere can play tricks with the thin light rays reflected from it to our telescopes. If there were some other way...

In 1956, Mars was in perihelion — and thus as close to the sun (and the earth) as it comes — and in opposition at the same time. When in opposition, the sun, Earth, and Mars are in a straight line, and scientists enjoy the full benefit of Mars's reflected light. Thus, in 1956, Mars was at its minimum dis-

tance from Earth, about 35,000,000 miles, and as bright as it could be. That year, Dr. William M. Sinton made a spectroscopic analysis of it. He repeated his test when Mars was in opposition again last year. Dr. Sinton made a surprising discovery.

He knew that all organic molecules show a strong absorption of infrared light at a wave length of about 3.4 microns (0.00013 in.). Figuring that a dried maple leaf and two lichens would be similar to Martian vegetation, he studied their spectra with his spectroscope. All three showed absorption (or non-reflectivity) of light in the 3.5 micron band. He reasoned that similar absorption in the light from Mars would show the presence of organic molecules. And vegetation would be the most likely explanation of the presence of organic molecules.

Once he had set up his detector of the radiation, he mounted the apparatus on the 200-inch Hale telescope of the Mount Wilson and Palomar Observatories. During four nights, he took four-minute readings on each of five wave lengths between 3.3 and 3.6 microns. When he reduced his data, he found a definite depression — indicating absorption — in the curve at about 3.6 microns. In short, he found evidence of organic molecules. Says Dr. Sinton, "This evidence and the well-known seasonal changes of the dark areas make it extremely probable that vegetation in some form is present." He adds that whatever the vegetation may be, it must have some regenerative power. Otherwise it would have been covered long ago by drifting ocher dust.

From the brilliant Dr. Hubertus Strughold, father of space medicine, came another suggestion — a simple way to test the Martian vegetation theory in a series of jars. "Why not," said Strughold, "raise micro-organisms under Martian conditions right here on earth?" Surely, he argued, if micro-organisms that have been coddled by Earth's gentle atmosphere can grow in a simulated Martian environment, then Martian micro-organisms would thrive on their own planet.

The "Mars jars" would have a practical purpose, too. Man will have to carry his atmosphere with him in a pressure suit when he visits Mars; to ease his oxygen-supply problem while there, perhaps he could force organisms raised in the jars to flourish on Martian soil and produce oxygen as needed.

Under Dr. Strughold's direction, Lieutenant John A. Kooistra Jr. of the USAF School of Aviation Medicine, Randolph AFB, collected soil samples containing bacteria. He took them from MacGonagal Pass on the icy slopes of Mount McKinley, the Grand Canyon, and the Painted Desert in Arizona. Some had a high lava content — a few astronomers think that Mars's dark areas are deposits of lava dust. Most of the samples were flinty red sandstone.

The next step was to determine the number of bacteria in each sample: the yeasts and molds, the aerobic spore-formers, and the heterotrophic organisms (they obtain nourishment from organic matter). Then Lieutenant Kooistra carefully dried out several samples until their moisture content was less than 1 per cent.

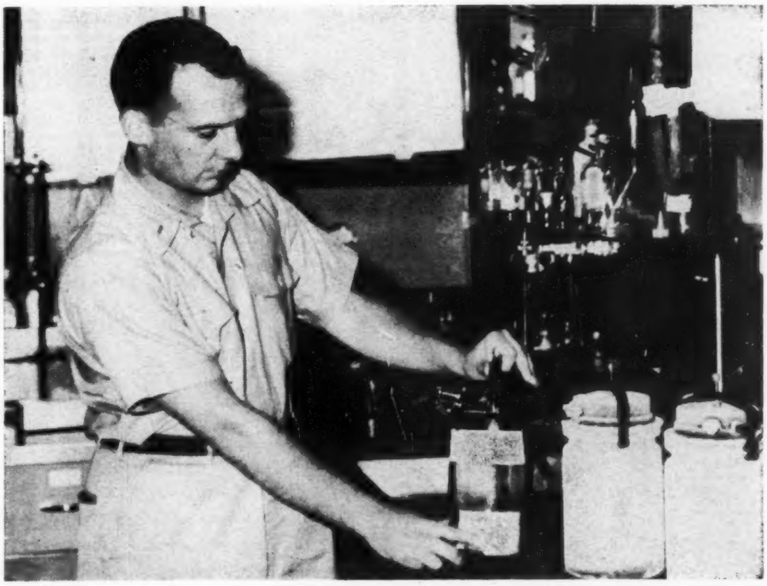
He filled several Brewer jars with commercial nitrogen, reducing the pressure to the equivalent of 55,000 feet on Earth and "sea level" on Mars, and popped his soil samples into the jars.

Now he had subjected "Martian" soil to a "Martian" atmosphere. Next step was to simulate the Martian day. This was easy because Mars's day (24 hours, 37 minutes) is almost like ours. Lieutenant Kooistra placed his little Brewer jars in the refrigerator at night (—25°C.) and took them out when he reported to the lab in the morning (25°C.). Now he had simulated the Martian climate except for solar radiation.

Ten months later, he found that while some micro-organisms — like the yeasts — had withered away, others had flourished in this brutal climate. Anaerobic bacteria (they live without free oxygen) had done particularly well. In one sample of heterotrophic organisms, the count increased from 54,000 to 1,033,333.

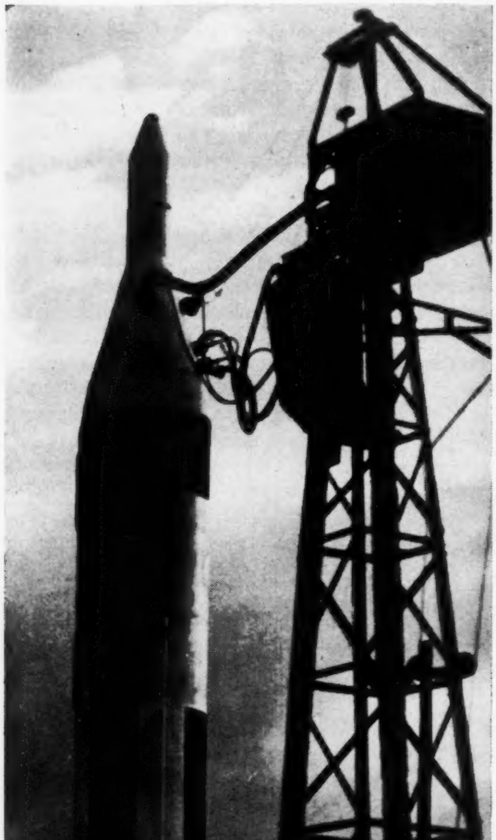
Lieutenant Kooistra did not draw any definite conclusions from his experiment. He took the survivors and popped them back into the jars for further tests of their growing power; he also began experiments with higher forms of life — mosses, lichens, and algae. But it would seem that if Earth-born micro-organisms can survive under Martian conditions, the dark areas on Mars may indeed be growing vegetation.

— U.S. Air Force photo



IN 'MARS JARS,' Lieutenant Kooistra grew bacteria under 'Martian' conditions.

— Photos from Lockheed Aircraft Corporation



Polaris test missile (*left*) squats on its pedestal-launcher before test firing. After launch (*above*), it seems to rise on a pillar of flame.

The Navy wanted a solid-fuel, sub-based missile. It got just that in the form of

POLARIS: flying torpedo

By Jules Bergman

■ Early next year, a drama that can be described only in superlatives will begin deep in the Atlantic. Officers aboard the biggest nuclear submarine ever built will give crisp final orders. Then a brace of the deadliest weapons ever carried on any ship will roar out of their launchers, only minutes apart. Propelled by gas, they'll break through the surface, hover over the whitecaps, ignite, and roar off for targets 1,200 miles distant. The Navy's Polaris, a new Intermediate Range Ballistic Missile, will be "on station." It's the most elusive and one of the deadliest retaliatory weapons in history.

Polaris may well be the biggest advance in missile-making since the first V-2's. Originally a nightmare of complex problems, Polaris is now a missileman's dream come true — the end result of an unbelievable saga of scientific breakthroughs. It is as different from the average missile as a Thunderbird is from a Stanley Steamer.

Only two years ago, many of the nation's top missilemen said Polaris was an impossibility, for the Navy wanted a missile that was propelled by solid-fuel rocket engines. It considered the liquid-fuel missiles — with their dangerous volatility, bulkiness, and large fuel-storage requirements — too tricky to handle on shipboard. A joint Army-Navy board had been working on a solid-fuel version of the Army's Jupiter IRBM for possible seagoing duty. But this was scrapped on the grounds that it was too large for submarine use.

At that time solid fuels were known to have a major defect that weighed against their use in missiles: they were often temperamental. Basically, solid fuels have much in common with the explosive powder in a firecracker. The problem was to keep solid-fuel missiles from behaving like firecrackers: they might go off in one brief explosive burst, instead of burning at a controlled rate.

Fortunately, a number of scientists felt that it would be possible to develop solid fuels that would burn at a controlled rate. But it would take a massive research and development program to find out whether these scientists were right. And on top of that, no one knew for sure whether a missile could be launched underwater.

The Navy was faced with a great decision. Should it put a large portion of its shrinking budget into Polaris, a bird that might never fly? Should it do this when new ships were badly needed to replace World War II vessels that were fast wearing out and costly to maintain? The Navy decided to take the chance.

Lockheed's missiles and space division was assigned the job of developing the Polaris airframe. Aerojet-General Corporation was to tackle the tough problem of perfecting a high-powered, solid-fuel power plant. Even while this work was going on, underwater test launchings were started.

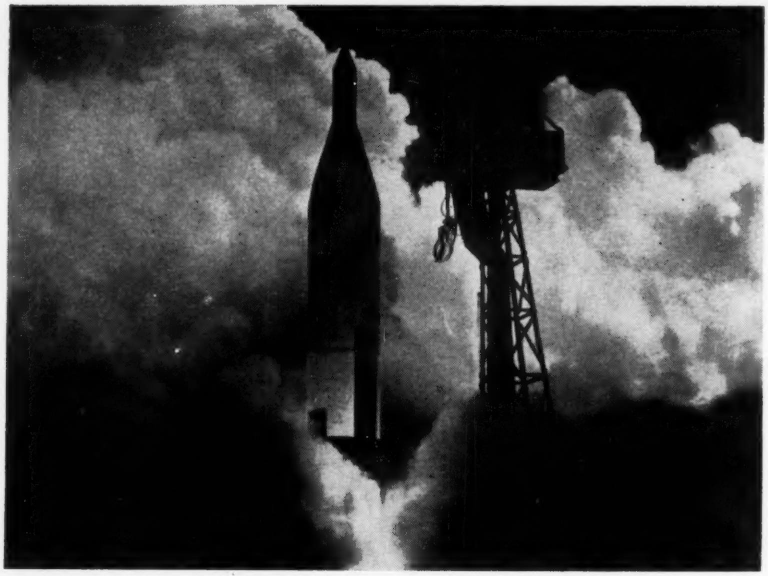
The first tests, called Operation Peashooter, were conducted on the beach. Then came Operation Pop-up, at San Clemente Island off the southern California coast. In a series of tests from a submerged launcher, the underwater feasibility of the launching mechanism was proved. These tests proved that a bird could be triggered underwater, sent to the surface by inert gases, and, when clear of the water, fired.

One major launching problem remained. A missile launching pad is a stable platform, but a ship moving in water rolls, heaves, and pitches. What effect would this have on the accuracy and directional stability of a missile? To find out, Lockheed built a launching mechanism known as a ship's motion simulator — it goes through the same motions as a ship at sea. Polaris test missiles will soon be fired from the SMS, which has been installed at Cape Canaveral. After these tests are completed, the missile will move to sea aboard the U.S.S. *Observation Island*, a special vessel converted for test purposes.

Just a year after the Navy disclosed its plans for Polaris (which was named after the North Star), the first Polaris test vehicle was fired. Since then, a whole series of test firings have been made to check guidance and propellant systems. In missile testing, early failures are accepted as routine. But the Polaris tests have come off fantastically well. Of twenty-seven vehicles fired, twenty-two have been completely successful. The last several test missiles have been quite similar to what the final Polaris will be like. All they lacked were certain internal refinements still under development.

The Navy had the close co-operation of the Air Force in developing the Polaris. The Air Force's Lockheed X-17, a solid-fuel ballistic test missile, provided priceless data — and proof, for the skeptics, of solid-fuel reliability.

The secret of a successful solid fuel lies in its grain — the actual physical form in which it burns. To burn, of course, the fuel must be combined with an oxidizer. The two together are known as the propellant. The grain of a propellant must be smooth-textured, compact, and evenly distributed. It must burn smoothly and uniformly on all its exposed surfaces. And no layers under the surfaces must detonate.



Bottle-shaped Polaris test missile is outlined against billowing smoke at lift-off.

Developing the right grain for Polaris was a thorny task. Aerojet came up with a star-shaped grain configuration. This provided a larger burning surface than would have been possible with a simple cylindrical shape. To hold the solid propellant together, Aerojet used polyurethane, the synthetic from which foam rubber is made. It's easy to fabricate, crack-resistant, and relatively cheap.

New alloys were developed to withstand the intense heat of the burning fuel. These were checked out in thousands of static tests. In other tests, Polaris was aged, frozen, heated, and vibrated. Purpose: to learn how well the missile would hold up under long periods of storage, under the temperature extremes of flight, and under the constant buffeting at sea.

The Polaris was now well along. But major and minor hurdles remained. The solid propellant, once ignited, burned all the way. There was no way of stopping it to terminate the missile's thrust. (This is easily done in liquid-fuel missiles with the timed shut-off of a fuel valve.) Thrust cutoff is critically important in aiming a missile. A 1,500-mile bird aimed at a target 1,200 miles distant, for example, will overshoot the target unless its power plant can be shut down at the proper time. Lockheed's Polaris chief, L. Eugene Root, now reports that the problem has been licked. A thrust-cutoff device gives the solids more precise control than the liquids.

Still another problem concerned over-all design. Polaris not only has to "fly" but "swim." And the fact that it is to be launched underwater dictated its design. In its final form, Polaris resembles no missile ever launched. It has been called a bowling pin and a Coke bottle by those who have seen it. Its odd shape actually makes it aerodynamically unstable.

This instability has been overcome by two means. The already-mentioned thrust-cutoff device, which makes the rocket thrust controllable, plays a vital part in making Polaris fly right. The Navy now has let the other part of the secret out. In what the Pentagon calls a "major scientific breakthrough," a movable steering nozzle has been developed for Polaris. Made partly of molybdenum, the steering nozzle precisely controls the direction of the missile's flight in spite of the intense heat of its exhaust.

This major step forward in the development and technology of solid propellants has sweeping implications. It will give Polaris greater accuracy, range, and reliability. It will allow the use of even more powerful solid fuels. And it will clear the way for Polaris's big brother, Minuteman. This is the Air Force's solid-fuel bird that is being designed for both intermediate and intercontinental range. It will first supplement and finally (by 1963) replace the Atlas and Titan ICBM's.

Polaris is further steered in flight by controls called Jetevators — small rings attached to the four thrust nozzles at the base of the rocket. These can be moved in flight to alter direction.

Almost all data about Polaris is still classified. But we do know it's far smaller (about 28 feet long) and much lighter (about 28,500 pounds) than any other long-range bird now in use. As a result, the new Fleet Ballistic Missile Submarines now being built will each be able to carry sixteen Polaris missiles. These will be housed in individual vertical tubes. They will be ready to go after a countdown of only a few seconds. Nine of the nuclear-powered Polaris submarines have been ordered, and five are already under construction. The first will be finished late this year.

The inertial guidance equipment for Polaris is being developed by the Massachusetts Institute of Technology and the General Electric Company. This equipment will enable the bird to make whatever corrections are necessary to put it on course to the target. Polaris will be more accurate than most of the big liquid-fuel missiles now in operation.

Perhaps the most remarkable fact about Polaris is the short time in which it has been developed. This missile will be ready for firing aboard atomic subs in 1960 — barely three years after the program was announced.

Cruising hundreds of feet below the ocean surface and able to stay at sea for a year, Polaris-equipped nuclear submarines may prove one of the greatest deterrents to war the world has ever known. Constantly on the move, they will be almost invulnerable to any surprise attack. They will be an insurance policy against aggression for the free world.

By James Blish

The shadowy figure of Roger Bacon

We know little about his contributions to science — except that he was apparently one of the first men to insist on the experimental method

Luckily, we know a good deal about most of the major scientists of history — people such as Newton, Avagadro, even Ptolemy. If we know relatively little about their personal lives, we can at least say with some assurance what they contributed to science as a whole.

But the contribution of one early scientist — Roger Bacon — is shrouded in mystery. Bacon was a medieval philosopher-scientist (1214?-1292). His name pops up frequently in accounts of the history of science. But so much myth has accumulated around his name that it's hard to separate fact from fiction.

It has been said, for example, that Bacon wrote a great many books about the sciences at a time when most of the great thinkers of his age were simply repeating themselves. We are not sure that this is *exactly* true. It has been said that Bacon was one of the great magicians of his era, probably in league with the devil. This is a myth that arose long after his death. It has been said that Bacon was one of the founders of scientific method and one of the first advocates of experiment as a way of knowing nature. This is how he saw himself, and he may well have been right. Now, seven centuries later, we probably have to take his word for it, especially since we can find nobody else in history who has a prior claim.

But even here we are entitled to reserve judgment. For the one thing we know positively about Roger Bacon is that he was a spectacular liar.

Bacon thought of himself as one of the most important thinkers of his time — and perhaps he was right. But of the many other great minds of the period, not one thought Bacon worth noticing. He claimed to have studied under two of thirteenth-century England's greatest teachers, Adam Marsh and Robert Grosseteste. What Bacon wrote about these two men is so full of intimate detail that we can hardly doubt that he knew them. Yet neither thought enough of him to mention his name in the many letters each wrote.

At one point, Bacon compiled encyclopedias of the sciences at the command of the Pope and sent them to Rome. Yet the Pope died without even letting Bacon know that he had received the books. Bacon's own account of such events is so colored by bitterness and jealousy that scholars are still quarreling about what actually happened and how important it was to the history of science.

And yet it's not so surprising that his contemporaries should have ignored him. In an age when science was almost wholly a stagnant puddle of ancient and mostly incorrect dogmas, Bacon was apparently the first to plead that experiment and only experiment could justify theory. In fact, the very term "experimental science" was his invention.

Many of the facts of Bacon's life are hazy. He was apparently born of a moderately wealthy family in the southern English town of Ilchester. It is believed that he entered the then new Oxford University at the usual age of 13. There, he may have studied under Marsh and Grosseteste. There is no record of what subjects he studied.

Somewhere between 1241 and 1247 the young Roger taught the scientific works ("the books of nature") of the Greek philosopher Aristotle at the University of Paris. We have transcripts of several of his lectures. He was probably, as he claims, the first man ever to teach the Aristotelian books of nature at Paris. But this again is a question that may never be answered.

Though the French university was then crammed to bursting with great minds — including such giants as St. Albertus Magnus and St. Thomas Aquinas — Roger Bacon was the only one who saw something that no man before him had had the clarity of mind to see. All the sciences being taught in Paris were being taken from books — none from actual experience with nature. Furthermore, many of the books, like those of his own beloved Aristotle, were as old as or older than Christendom itself; and the commentaries on them were nearly as antique. Finally, almost all these books were being read in hopelessly bad translations.

Roaming the narrow, mucky streets of Paris, he searched for men who were actually *working* with nature, not just passing on the words of long-dead "authorities." The man he found and wrote about was as ignored by the great scholars of the university as was Bacon himself: a minor French nobleman who called himself Peter the Peregrine. (A peregrine then was a man who had been to the Holy Land.)

This man, Bacon wrote, was a real experimenter. He did not feel

too proud to handle the materials he talked about. He diligently collected the stories of travelers. He sent out agents to investigate stories he could not check himself. Peter eventually wrote a letter about his experiments in magnetism that had a decisive influence upon the whole history of physics. In fact, the next important writer on magnetism — William Gilbert, in 1600 — was so impressed with Peter's views that he attributed them to Bacon!

While in Paris, Bacon did some experiments himself. Most were not original, but were simple tests of notions long taken for granted. Some were enormously expensive. To test whether or not a diamond really does dissolve in goat's blood, for instance, you need to buy (1) a goat and (2) a diamond. All in all, Bacon reported, he spent almost his entire fortune on books and experiments — about £2,000, or close to $90,000 in terms of U.S. money today.

He also seems to have spent much time doing very simple and inexpensive experiments, such as spraying mouthfuls of water into the air and trying to analyze the brief rainbows produced by the sunlight in the spray. Here his growing interest in theory is evident; he was already trying to formulate new laws of optics, aided by mathematics, his favorite science.

Many practical discoveries were mistakenly attributed to Bacon by poets and playwrights of later centuries. But it *is* probable that he discovered gunpowder independently, some years before the Arab knowledge of this invention percolated into Europe. This discovery probably magnified the story that he had sold his soul to the devil. Bacon himself, however, was never primarily interested in the practical; he was a theorist, not an Edison. It was the method that interested him, not the results.

In 1250 or thereabouts, Bacon returned from France to teach at Oxford. He speedily ran into trouble. His new ideas were not well received. His already growing reputation as a magician may well have been confirmed in the eyes of others by his introducing into the classroom simple scientific demonstrations. In addition, he was openly contemptuous of Oxford's new lecturer on Aristotle. By 1256, the Franciscan Order — of which Bacon was now a member — ordered him back to Paris. He was forbidden to write or teach any more except under the close supervision of the Order.

In this critical period, Bacon abruptly proved himself to be a master politician. By long, careful, and secret negotiations, he arranged to have Pope Clement IV himself send Bacon a direct order to write a summary of the value of the sciences for the Christian world. Though Bacon no longer had money for copyists, he managed to borrow about fifty pounds and then undertook to write an enormous encyclopedia of science.

In fact, he produced no less than three such works, all in a period of eighteen months. The first, called *Opus Majus,* or "The Large Work," fills two heavy volumes in English translation. This he sent to Rome via diplomatic courier. Then, fearing that it might be lost on the way, Bacon wrote a summary, called *Opus Minus,* "The Small Work." It was about the size of a long historical novel. This he sent to Rome via his apprentice. Finally, for safety's sake, he wrote a summary of the summary. It was called *Opus Tertium,* or "Third Work," still a book in itself.

Much of the science in these three great letters — for Bacon thought of them as nothing more than that — is now dead. Their importance lies in their discussions of scientific method itself. Here for the first time in history is a clear discussion of why tests and measurements must be at the foundation of every theory, no matter what field of knowledge is being studied. Furthermore, said Bacon, you must always be wary of the human mind, which usually sees only what it wants to see, not what is actually there. Even if the experiment is properly designed, four sources of error can creep in to fog the experimenter's sight:

1. *Authority,* which pretends that it already knows the answer.

2. *Custom,* which says that anything thousands of people have believed for thousands of years has to be true.

3. *The mob,* which believes many things that are not true and tries to enforce them by sheer numbers.

4. *The pedant,* who uses his high position to enforce and conceal his own ignorance.

These four forces are still enemies of scientific advance. Thanks to Bacon, however, we have learned to be wary of them.

But in the thirteenth century these were not welcome truths, and Bacon as a person did little to speed their acceptance. Genius though he was, he appears in his own writings to have been a spiteful, hot-tempered, and envious man who was not content to let his work speak for itself. From this point on in his life he made enemies wherever he turned.

For a while Bacon was allowed to resume teaching at Oxford. But around 1277 he was thrown into a prison for heretics, along with other Franciscans.

Freed in 1290, he barely saw the sunlight again before he embarked upon another of his huge projects, this time an encyclopedia of theology. But it is plain to see, from the opening chapters of this book, that he was by that time old and broken. He died on June 11, 1292.

Today it no longer matters that Bacon was wrong in his theory of how the eye works, and that we have had to discard his primitive notion of the ether. We no longer care that he added nothing important to the theory of how rainbows are formed; or that he probably didn't invent spectacles, the submarine, or the telescope; or that he was as superstitious as any other man of his age, a believer in astrology and magic. Nor does it matter that as an experimenter he was not very original.

What counts is that he was apparently the very first great mind in the West to insist that experiment is the only trustworthy way to wring answers from nature. His studies of how to make an experiment trustworthy still compel us to ask ourselves one of the hardest of all philosophical questions:

How do we know what we know — and how do we test it?

Bacon the experimenter tested such ancient notions as the idea that a diamond could be dissolved in a goat's blood.

THE SUBTLE STORM

By John Brooks

In Middle Ages, people thought the strange night light of auroras looked like dragons.

PART I ■ Eight minutes after two o'clock, Mountain Standard Time, on the afternoon of Sunday, February 9, 1958, is a point in time that at least one staff member of the Sacramento Peak Observatory, in Sunspot, New Mexico, is likely to remember as long as he lives. At that moment, as he was watching the sun through an instrument called a monochromatic heliograph, which shows the solar surface in such a way that it appears gray and any bright spots or dark blemishes stand out clearly, he saw a sudden, explosive brightness appear in an area that a second before had been dark and cloudy. This was quickly followed by the lighting up of what appeared to be a network of filaments, something like those in a light bulb, in the same vicinity. Although the spectacle was just the sort of thing he had been waiting for, its exceptional brilliance made it the kind of breathtaking rarity astronomers dream about. It was all he could do to take his eyes away, but he remembered his duty and switched on a radio transmitter beamed to the International Geophysical Year World Data Center on Solar Activity, at the University of Colorado's High Altitude Observatory, in Boulder. He waited while the radio automatically transmitted five warning beeps, to alert the staff at the receiving end, and then, controlling his voice as best he could, said, as he remembers it, "Well, now, we've got a whopping big new flare here in Region ABOO. Looks as if it'll go Class Two or Two Plus, and it's still rising. Stand by for further reports."

This was the first word of the great eruption to reach the World Data Center, but within minutes similar bulletins were flowing in from observatories scattered over the half of the earth that the sun was shining on, and they caused chagrin as well as excitement, because the Data Center's own monochromatic heliograph was staring up at a dense cloud bank. From the incoming reports, though, it was clear that a major flare had erupted on the sun — a solar cataclysm that, in the prevailing opinion of scientists, spews an enormous stream of electrically charged particles out into space, sometimes in the direction of the earth, sometimes not. A characteristic of such flares is that they generally occur when there is an accumulation of a large group of sunspots, and such was the case in this instance. For the past several days, Boulder and a worldwide network of co-operating observatories had been keeping a sharp eye on a growing cluster of sunspots that had arbitrarily been designated Sunspot Region ABOO. At the moment, it was a little to the west of the sun's central meridian, in its southern hemisphere. It covered three billion square miles of the sun's face and constituted one of the ten largest groups to have appeared in the eighty years that sunspots have been systematically measured, so something special in the way of a flare had been anticipated. Like the milder rumblings before a thunderclap, seven smaller flares had been counted that day before the big one came.

Another characteristic of the greatest solar flares is that while they are going on, the sun sends out bursts of radio noise that, when picked up by special high-frequency receivers on earth, sound like sausages being fried. The big flare at ABOO was only four minutes old when the Harvard Radio Astronomy Station at Fort Davis, Texas, began hearing precisely that noise from a receiver tuned to four hundred and fifty-eight megacycles per second. It was so loud that Fort Davis classified it as "Magnitude Major Plus." In the next half hour, the sun began broadcasting equally abrupt and inscrutable messages on several other frequencies.

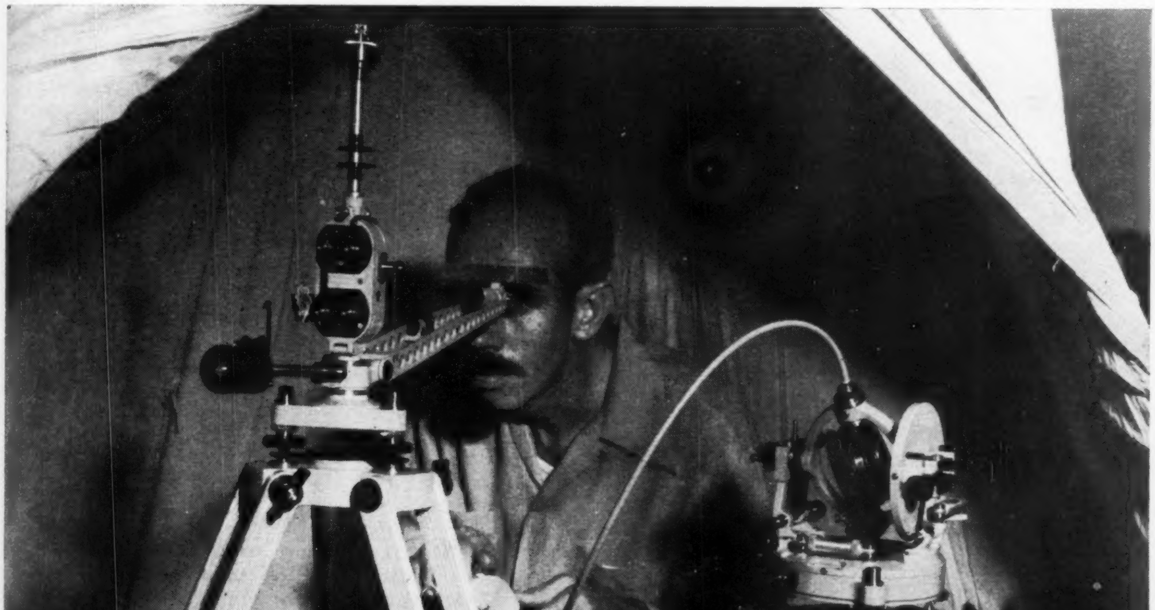
The dazzling glow on the sun and the bursts of radio noise kept up for just under two hours; then, at a few minutes of four, Mountain Time, the sun finally signed off the radio waves for the day, and at two minutes after four the flare disappeared from sight on the heliographs. A little later, Dr. Alan Maxwell, the director of the Harvard station at Fort Davis, called up his friend Dr. Walter Orr Roberts, the director at Boulder, to talk the phenomenon over. The two men agreed that the flare and the associated radio emanations had been of unusual intensity, and they compared notes on the available data, both of them being well aware that such manifestations are frequently, but far from invariably, followed about a day later by severe magnetic storms, which are little-understood terrestrial disturbances that are notoriously able to disrupt the operations of all sorts of electrical and electronic equipment, including transoceanic radios. After his chat with Dr.

Maxwell, it occurred to Dr. Roberts that, in his capacity as head of the World Data Center on Solar Activity, he should perhaps send an official advisory bulletin to the IGY World Warning Center at Fort Belvoir, Virginia, recommending the declaration of a Special World Interval — that is, a worldwide alert to IGY scientists everywhere to watch closely during the next couple of days for anything out of the geophysical ordinary. The more he thought about it, though, the less he felt that the evidence justified such a far-reaching step, so he contented himself with sending a routine teletype message to Belvoir telling the Warning Center about the flare, instead of requesting a Special World Interval. This, as he has subsequently gone out of his way several times to emphasize, was a mistake, because some twenty-eight hours later one of the greatest magnetic storms on record began.

In future years, it may be that the Weather Bureau or some Space Age equivalent will warn us all of approaching magnetic storms, just as we are now warned of approaching hurricanes, but at present the only Federal agency specifically on watch for them is the Bureau of Standards, whose Central Radio Propagation Laboratory, which is also in Boulder, issues forecasts about the magnetic weather through the North Atlantic Radio Warning Service and the North Pacific Radio Warning Service. These two branches, situated at Fort Belvoir and Anchorage, Alaska, have a list of communication systems, steamship companies and airlines, radio amateurs, and other interested parties, who are notified when any atmospheric disturbance that might affect their transmission seems likely. The forecasters at the Central Radio Propagation Laboratory are among the most valorous of prophets, since they are called upon to make their predictions with very little in the way of scientific knowledge to guide them. The strong likelihood that solar flares and noises have a connection with magnetic storms has been generally recognized for less than twenty years. Moreover, magnetic storms, while they are sometimes as big as all outdoors, can be as capricious as New England thundershowers. At any rate, the Central Radio Propagation Laboratory failed to detect the approach of the magnetic storm that followed the great flare of February 9th. A number of solar observatories that give the Laboratory forecasting advice called attention to the flare and the unusual solar radio noise, but the consensus of the Laboratory experts was that the noise wasn't typical of the kind usually associated with magnetic storms. As late as two and a half hours before the storm hit the earth, the North Atlantic Radio Warning Service prediction was that transatlantic radio conditions during the six-hour period ahead would be fair to good.

In view of the immense ignorance on the subject, it is perhaps not surprising that just about the only man who was skillful enough or lucky enough to have come somewhere near calling the turn on the storm should have done so without benefit of heliographs or short-wave receivers. He is John H. Nelson, propagation analyst (or radio weatherman) for R.C.A. Communications, Inc., the country's largest sender of commercial radiograms, and his office is a cubbyhole on the tenth floor at 66 Broad Street, in downtown Manhattan, where he can usually be found contemplating a diagram of the positions of the various planets in relation to the sun. His routine is to issue two kinds of forecasts — daily ones, covering the twenty-four hours immediately ahead, and long-range ones, which may cover thirty days or an even longer period. Nelson's daily forecasts are made by relatively conventional means, based

— National Academy of Sciences IGY photo



Geophysicist James H. Haden is shown operating an earth inductor and galvanometer. This instrument, designed for use in the field, can make precise measurements of the angle of dip, or inclination, of the earth's magnetic field.

— Official U.S. Navy photo

The solar flare associated with the magnetic storm described in the article occurred in the sunspot region marked with an arrow. Photo was taken on the day before the flare erupted.

on constant study of electrical conditions in the upper air, but for his long-range predictions he uses a private system based on a correlation he has noticed between magnetic phenomena and the way the planets are lined up with the sun. His system causes a lot of headshaking in sober scientific circles, but over the past few years he has been right often enough to keep R.C.A. Communications, Inc., happy. Nelson was at home in bed with the flu when the sun started acting up on Sunday, and he stayed in bed on Monday, too (it was the first weekday he had taken off in a month), so he didn't issue his customary short-range forecast. However, when he put out his regular monthly forecast, toward the end of January, he had known that Venus and Pluto were going to be in a dead-straight line with the center of the sun on Monday night, and that on previous occasions the same arrangement had coincided with fierce magnetic storms; accordingly, he had predicted, more than a fortnight in advance, that transatlantic radio communication would be no better than fair. This turned out to be an understatement, but since it contrasted with a prediction of "fair to good" for the five previous nights, it was sufficient warning to put R.C.A.'s outposts on the alert for trouble. Thus Nelson, far from having to apologize for being laid up on the crucial Monday, was subsequently able to accept congratulations all around.

The storm, when it struck, was a classic example of perhaps the oddest sort of foul weather the earth is plagued with. In the strictest sense, a magnetic storm is not weather at all, since it has no direct relation to wind, rain, snow, hail, lightning, or any of the other standard concomitants of meteorological disturbances, yet scientific usage unanimously sanctions the employment of the word "storm" to describe it. In other ways, too, it is a storm to delight lovers of paradox. Although in terms of energy it is vastly more violent than any tornado or hurricane, and although it is sometimes so widespread that it affects every square inch of the earth's surface, completely blanketing the globe within the span of a few seconds, it is so subtle that it can be detected only through its effects on electrical and magnetic equipment or through the radiant auroral displays that accompany it. The real force of the storm gives no sign of its presence to the unaided senses. Until about a century ago, when the kind of equipment that magnetic storms affect first came into use, they were not even known to exist. Down through the ages, they had, no doubt, raged over the earth at intervals, confusing mariners by causing compass needles to waver, but otherwise spending their force on a planet too electromagnetically innocent to suffer from them, or even to suspect their presence. Conversely, they seem destined to get increasing attention and to cause more serious trouble in the future: nobody knows what kinds of apparatus still undreamed of may come along to be thrown out of whack by their caprices.

In brief, a magnetic storm is a disturbance in which the earth's magnetic field — the force that makes a compass needle point approximately north — goes temporarily haywire. The greatest magnetic storms strike with such apocalyptic suddenness that, in the words of the British astronomer H. W. Newton, "it is as if the earth had been hit by a celestial shock-wave." They run their course in anywhere from a few hours to several days, and, during that time, periodically appear to subside, only to rise up to new peaks of activity. While their effects may sometimes be felt in the tropics, they are always most severe near the North and South Magnetic Poles, where they may cause compass needles to wander as much as seven or eight degrees away from their regular position and lead to a variation of considerably more than 10 per cent in the force of the earth's magnetic pull. In the latitudes within which the United States lies, the compass may on rare occasions wander as much as three or four degrees afield and the magnetic force vary by 6 or 8 per cent.

It is during and just after the height of these fluctuations that auroras appear in unaccustomed latitudes. The aurora — called "borealis" in the Northern Hemisphere and "australis" in the Southern — is one of the most mysterious of visible celestial phenomena. Scientists have theories, hypotheses, and vague general notions about it, but they do not know exactly what takes place when an aurora spreads across the heavens. Some of them feel that if they ever really come to understand the aurora, they will have solved the riddle of the universe itself. The strange lights are not even easy to describe. In attempting to classify the various forms that auroras assume, the most prosaic astronomer tends to become rather impressionistic, leaning heavily on words and phrases like "haze of luminescence," "quiet arcs," "quiet luminous bands," "draperies," and "bundles of rays." Most auroras are greenish yellow ("the color of

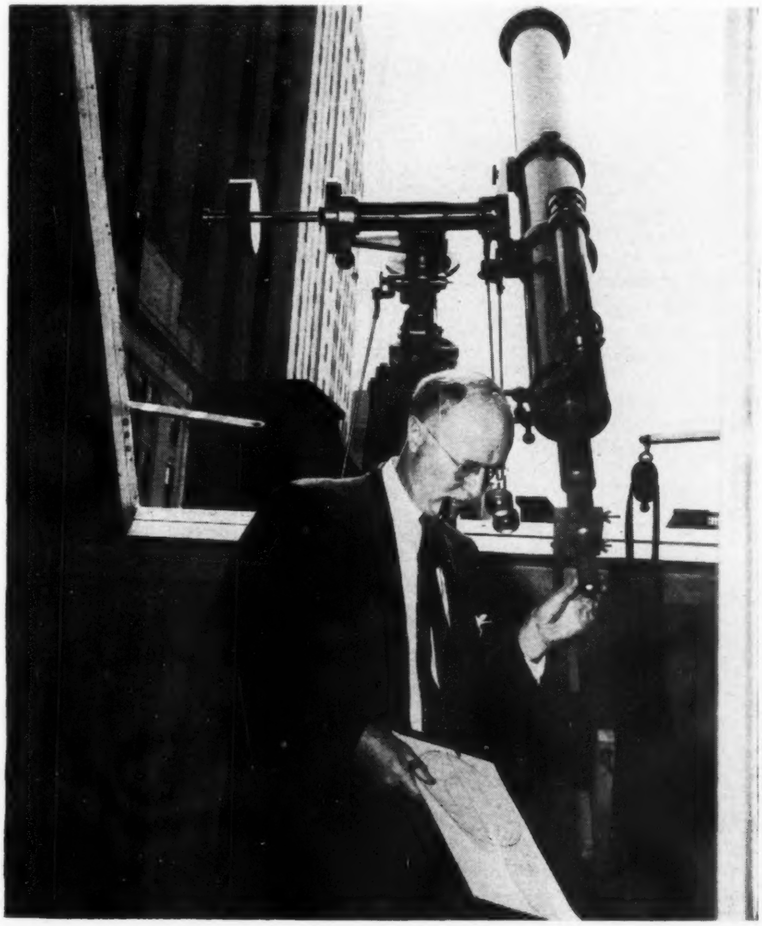
plants grown in the dark," it has been called), but they often take on shades of red, green, blue, and violet, and almost all colors have been seen in them at one time or another. In Norway and other arctic regions, and even in England, very strong auroral displays are often said to be accompanied by clearly audible sounds — crackling, hissing, or sharp reports that sound like the snapping of dry branches. In respect to this fascinating point, most scientists are skeptical but, by reason of their ignorance, necessarily receptive.

An aspect of auroras that has never been questioned by anybody who has ever seen one is their power to call forth feelings of awe, wonder, and sometimes fright. In the Middle Ages, people thought they looked like dragons, or, sometimes, like battles waged from towers and ships. "Indeed, some affirmed very plainly that fiery dragons with twisted heads were seen," a Canterbury astronomer wrote of an aurora that appeared in 1177. And more than five centuries later, a great display on March 5, 1716, was likened, in as sober a publication as the *Philosophical Transactions* of the British Royal Society, to the cupola of St. Paul's, to a painter's representation of glory radiating around the Name of God, and to the medals on the breasts of the Knights of the Garter. On a more pedestrian scientific plane, what is reliably known about auroras is that they appear most frequently and most intensely in two doughnut-shaped zones, one looped around magnetic north and the other around magnetic south. The center of the northern auroral zone runs through central Alaska, across Canada, lower Hudson Bay, and Labrador, to Iceland, Scandinavia, and, finally, Siberia. The southern zone is so situated that most of its auroras are seen only by the gulls, seals, penguins, and well-bundled human insurgents who frequent the edges of Antarctica. In both zones, nocturnal displays are common even in times of relative magnetic calm, but in the temperate and tropical regions — and also in the extreme polar regions, beyond the doughnuts — auroras occur much less often. When they do occur, it is always during magnetic storms. At such times, exceptionally brilliant displays are sure to appear in the auroral zones, but that is only the beginning. Auroras may be seen — flickeringly, and often briefly, but sometimes with an intensity of illumination rivaling that of the full moon — anywhere in the temperate regions, and even in the tropics. Almost the whole earth may be, for a few hours, appareled in celestial light.

[*To be continued in May* 5 SW]

— National Academy of Sciences IGY photo

Japanese field magnetometer, used for measuring the strength and direction of the earth's magnetic field, is operated by U.S. Coast and Geodetic Survey scientists.



— RCA Communications, Inc.

Sunspots are observed by RCA's John Nelson. He is projecting them onto a map of the sun. Telescope is located atop the company's offices in downtown New York.

Science in the news

Eel-migration theory is disputed by zoölogist

A long-held theory about the migration of eels has been challenged by Dr. Denys W. Tucker, zoölogist at the British Natural History Museum.

The theory: Two species of eel, one European and one American, breed in the Sargasso Sea. This is an area of still water located in the middle of the Atlantic Ocean roughly opposite Florida. The American eel reaches the Sargasso Sea by migrating east from North America. The European eel swims west from such far points as the Baltic and Black Seas. After breeding, the parents die. But the offspring find their way back home. The young American eel takes a year to swim back to its home rivers. The European species may take as long as three years to return to its home. When they mature, both species swim back to the Sargasso to breed.

Dr. Tucker says this theory is almost impossible. He doubts that European eels migrating from the eastern end of the Mediterranean Sea could find their way out of the Strait of Gibraltar. And, he says, an eel embarking from Copenhagen would almost certainly get lost in the complicated counter-currents of the North Sea. That is, if it managed to escape the Norwegian Current, which sweeps toward the Arctic Ocean.

Dr. Tucker's own theory: Only American eels breed in the Sargasso. Lucky ones reach the warmer, southerly waters of the Sea; their offspring return to America. The less fortunate eels breed in the Sargasso's northerly waters whose cold inhibits the growth of their young. These young eels are caught in a great clockwise whirlpool around the Sargasso Sea and are carried across the Atlantic to European shores. They never return to the Sargasso to breed. European eels, he concludes, are of American ancestry.

Fallout of strontium-90 is highest in U. S.

The Atomic Energy Commission has reported that the dangers of nuclear fallout, especially in the United States, may be greater than it had previously indicated. This conclusion stems from two Government findings: (1) radioactive particles hurled into the atmosphere by nuclear explosions may be falling to earth faster than previously supposed; (2) the fallout rate of the most dangerous particles, strontium-90, is highest in the U.S.

When strontium-90 falls to earth, it is absorbed by plants. Since many of these plants are eaten by man and animals, strontium-90 eventually finds its way into the human body. There it tends to accumulate in bones, and enough of it can cause bone cancer. Strontium-90 and other radioactive particles can also cause hereditary changes that are harmful to offspring.

The Government findings were based on studies of air and soil samples. No figures were given on fallout in the U.S. But figures on general fallout indicate that radioactive debris from a nuclear explosion settles down on the earth over a two-year period. This fallout rate is three and a half times as great as that given in a previous Atomic Energy Commission estimate.

As a result of the reports, a complete review of radiation hazards will be made. First step: a comprehensive study of biological effects of radiation.

Radio waves influence behavior of cells

Radio waves have startling effects on cells, the basic units of all living things. This discovery was made by three scientists at the New England Institute for Medical Research. It suggests that radio waves may be a valuable tool in studying life processes and in fighting disease.

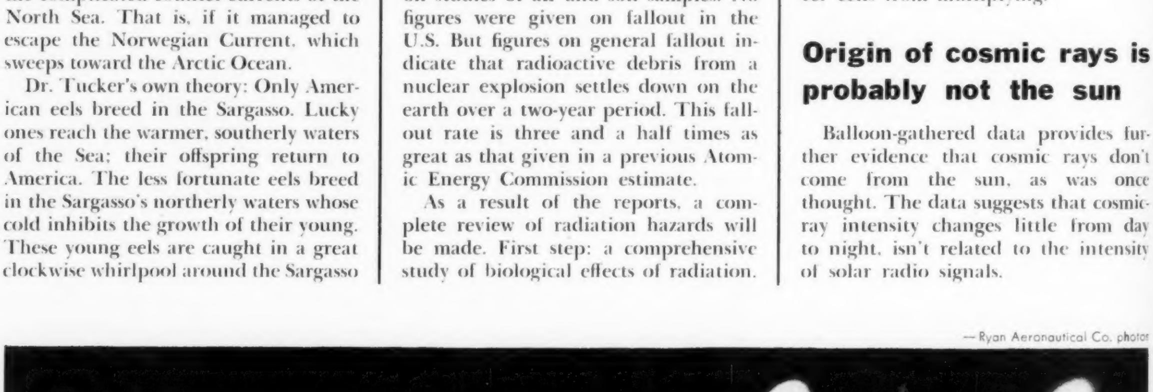
In one experiment the scientists placed tiny one-celled animals called *Euglena* on a glass slide between two electrodes. When radio waves were passed between the electrodes, an electromagnetic field was set up. All of the *Euglena* promptly lined up and swam parallel to the field's lines of force. Their action resembled the way in which iron filings line up along the lines of force around a bar magnet.

When garlic plant cells were exposed to the electromagnetic field, the stick-like chromosomes in the cells reacted in a similar manner. Chomosomes carry the material that controls heredity. When they assumed the pattern of the lines of force, they were unable to divide and reproduce. It is possible that waves could be used to keep cancer cells from multiplying.

Origin of cosmic rays is probably not the sun

Balloon-gathered data provides further evidence that cosmic rays don't come from the sun, as was once thought. The data suggests that cosmic-ray intensity changes little from day to night, isn't related to the intensity of solar radio signals.

—Ryan Aeronautical Co. photos



Jet smoke rings like these are helping engineers to make quieter jet engines. Oil is injected into the exhaust of an operating jet engine to make smoke. Shape of the smoke ring blown by the engine is determined by the design of the muffler used to suppress the jet's noise. Smoke rings are photographed at night with the aid of a powerful searchlight aimed at the exhaust through a narrow, slitlike opening. Sound is picked up by microphone. Sharp, distinct rings mean noise. Diffused rings indicate quieter operation. Thus, rings indicate best designs.

Scientists are puzzled by ash on ocean floor

What spectacular event in the earth's past could have laid a layer of white ash over a vast area of the eastern Pacific Ocean floor? Did the earth collide with a comet? Was there a simultaneous eruption of many volcanoes?

These questions are tantalizing scientists at Columbia University. Recently, scientists aboard the university's research vessel, *Vema*, discovered the ash. The white ash forms a layer that extends at least 750 miles north of the equator and 825 miles south. Its thickness ranges from one to twelve inches. The ash is free from submarine life and ocean debris; this indicates that it may have fallen within a short space of time – within a year or so.

At present, scientists can only guess at the origin of the ash. Next step: to see if the same kind of ash exists in other ocean areas.

Radar contact with Venus made for first time

Radar signals have been bounced off Venus and received back on Earth. This marks the first successful radar contact with a planet. And it is a first step toward accurately measuring interplanetary distances by radar.

Traveling at the speed of light, the very high frequency radio signals made the round trip of some 56 million miles in about five minutes. The experiment was made by an M.I.T. research team.

The signals were "fired" from a radar antenna 85 feet in diameter. The power of the signals reaching Venus was only one-millionth their original power. And the power of the "echo" signals reaching the earth was only a tiny fraction of the power reflected by Venus.

These very faint signals were recorded on tape. To distinguish them from background electrical noise, the scientists used a powerful maser amplifier and a giant digital computer. The original signals had been coded to make them easier to identify. Even so, it took nearly six months for the scientists to be sure they had received the echo of their original signals.

When radar techniques are further refined, scientists hope to use them to "see" beneath Venus's cloud cover. Object: to discover whether the planet's surface is smooth or rough. They also hope to determine how fast the earth-size globe rotates. Another radar contact with Venus is planned for September, when the planet will again be close to the earth.

Chemical aids learning, animal tests reveal

The theory that learning is linked to a chemical reaction in the brain got a boost from recent tests at the University of California.

One of the chemicals that takes part in the brain's nerve activity is called cholinesterase. California researchers found that the amount of cholinesterase naturally present in the brains of rats varies with their inheritance. Rats with more of the chemical, the researchers discovered, are able to learn faster.

Could the relationship work both ways? the scientists wondered. Could the very act of learning affect the amount of cholinesterase present? To find out, they trained one group of rats to run through complicated mazes and left another group idle. Then they re-measured the amount of cholinesterase in each group. The trained rats showed increased amounts of the chemical, but the idle rats did not. More complicated tests made later confirmed the results.

Eventually scientists hope to answer this question: is there a chemical that could be given to "dull" animals to raise their cholinesterase level and make them "bright"? If so, the same technique might someday be applied to humans.

Scientists disagree over shape of the earth

A geologist has challenged the theory that the earth is pear-shaped. This theory, announced just recently (Feb. 24 *SW*, page 19), is based on irregularities observed in the orbit of the Vanguard I satellite. These irregularities reflect changes in the pull of gravity produced by irregularities in the earth's surface. As indicated by Vanguard's orbit, the earth is a sphere slightly flattened at the poles and pinched in very slightly in the Northern Hemisphere.

But geologist J. Lamar Worzel of Columbia University finds a flaw in this picture. He says the Northern Hemisphere, rather than being pinched in, actually bulges out in places. His findings are based on gravity measurements scientists have made over the world's oceans.

Why weren't these bulges reflected in Vanguard's orbit? The effects of gravity, Dr. Worzel says, are averaged together during a satellite's many swings around the earth. As a result, he says, some details of the earth's shape may be missed.

News in brief

• What lies beneath the antarctic ice? Findings by IGY scientists had led them to believe Antarctica might be a chain of islands rather than a continuous land mass. Now evidence gathered by a team of Russian scientists seems to refute the island theory. During a long over-ice trek, the Russian scientists set off dynamite blasts every thirty to fifty miles. Sound waves from the blasts traveled down through the ice, bounced back from underlying land, and were picked up by instruments. The soundings indicated that the land was continuous over a stretch of some 1,100 miles.

• Driving with no hands would become common practice under a highway-auto system proposed by Westinghouse engineers. A radar set attached to the front bumper of a car would enable it to follow a guide line painted down the center of a highway lane. The guide line would be coded with dots and dashes to stop the car at stop signs and to allow it to turn off at particular intersections. The driver could take manual control of the car whenever he wished, for passing and other purposes. An automatic braking system might also be included to keep a car from bumping the one in front of it. The new plan could be put into effect within five years, said one engineer.

• Fooling a fish isn't easy, two biologists at a New York State fish hatchery have decided. To cut down the numbers of the fast-breeding carp, the scientists have been seeking a poison that the fish will willingly swallow. They've tried nearly 1,500 different chemical combinations. But the fish have refused to nibble no matter how cleverly the poison is disguised. Carp are on the black list because they ruin the spawning grounds of other fish by rooting up lake and river bottoms.

• Spoons used by manlike creatures 500,000 years ago have been unearthed at Transvaal, South Africa. Made of animal bone, the spoons were smoothed by use. Anthropologists think prehistoric men used them to feed youngsters and toothless elders.

• Astronomers will be better equipped to study the half of the visible universe best seen from the Southern Hemisphere. A new observatory soon will be built near Santiago, Chile. The project is under the joint supervision of three universities: Chicago, Texas, and Chile.

Young scientists

HOW TO DO IT

Here are three techniques that may help you in your experiments — techniques that may lead you into interesting science projects

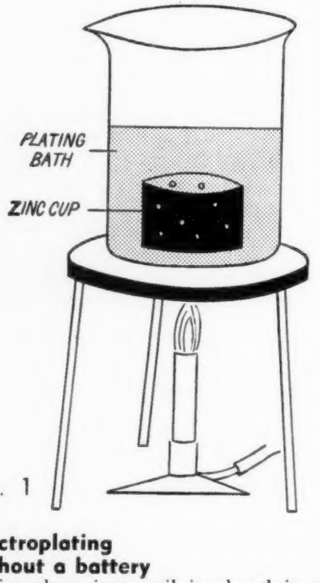


Fig. 1

Electroplating without a battery

If a clean iron nail is placed in a solution of copper sulfate, metallic copper will soon be seen to coat the nail. In an electrochemical reaction, the iron replaces the copper in the solution and the copper deposits on the nail. In general, the more active metal (iron, in this case) replaces the less active metal (copper) in the solution. Here, the copper emerges as metallic copper.

Since zinc is more active than iron, copper, or brass, you can electroplate small pieces of these metals simply by placing them in contact with metallic zinc in a solution containing the metal with which they are to be plated. Because zinc stands near the top of the electromotive series of elements, zinc will replace most common metals when it is put into a solution of one of them. The metal will then come out of the solution and form on the piece of metal. Here is a convenient way to do this type of electroplating.

Secure an old dry cell. With a hacksaw, cut through it about 3 inches from the bottom. Remove the zinc cup thus formed from the cell, and clean it thoroughly. Sandpaper the cup, particularly its inside, to expose a clean surface of zinc. Puncture the sides and bottom of the cup. Set it in a large beaker over a source of heat.

You are now ready to plate. The materials to be plated should be thoroughly cleaned and deposited inside the zinc cup. Then a solution containing the metal to be used for the plating is poured into the beaker and heated. To plate copper on brass, iron, or steel, dissolve 15 grams of potassium bitartrate (cream of tartar), 5 grams of sodium hydroxide, and 5 grams of copper sulfate in 250 milliliters of water. Pour the solution into the beaker so that it covers the zinc cup. Keep the plating fluid hot, and at the end of about 15 minutes remove the cup, flush the cup and contents, then rinse and dry the objects. Buffing the objects with a piece of fine steel wool will produce a shiny luster.

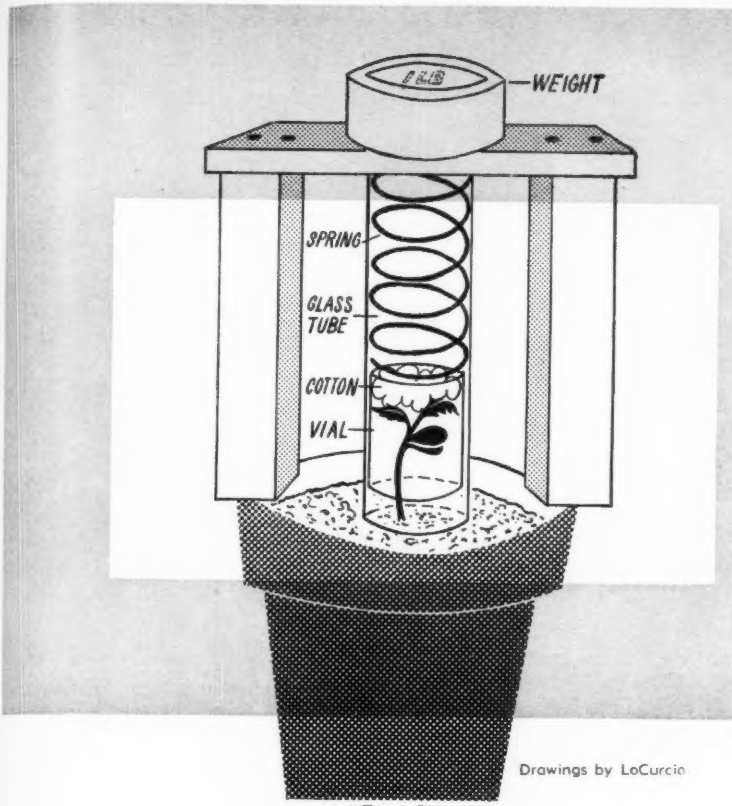
To plate nickel on copper or brass, use a solution of 10 grams of nickel ammonium sulfate in 250 ml. of water. Use the same method as for copper plating. Zinc may be plated on iron and steel by using a solution of 20 grams of zinc chloride and 5 grams of ammonium chloride in 250 ml. of water.

The study of electrochemistry is a fascinating area for project work. It has many applications in electrolytic refining, corrosion, and the manufacture of batteries. There are ample opportunities for anyone who can apply a knowledge of the electromotive series in novel ways.

Measuring the force exerted by a growing stem

As a seedling breaks through the ground and pushes its way upward, it can sometimes be seen to push aside rather heavy stones. Just how much opposition can the stem overcome in forcing its way upward? It's possible to get a quantitative measure of this force, as well as the pressure behind the growth, by means of the apparatus shown in Fig. 2.

Plant a lima bean seed in a small pot. When the bean seedling is about



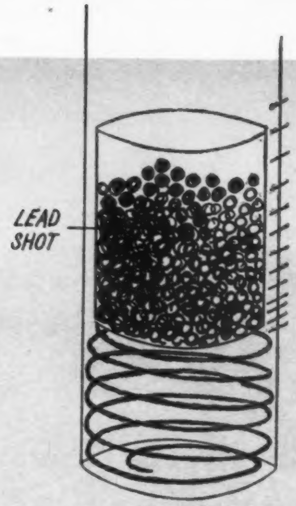


Fig. 3

Drawings by LoCurcio

Fig. 2.

an inch high, it will be ready for the experiment. Obtain a 6-inch length of 1-inch-in-diameter glass tubing and find a glass vial that fits inside. Then make a spiral spring of No. 18 brass wire by winding it evenly around a ¾-inch stick. Slip the glass tubing over the seedling and push the tubing an inch or two down into the soil. Place a piece of cotton in the bottom of the vial, invert the vial, and carefully lower it through the tubing onto the top of the growing seedling. Then insert the spring into the tube. (The spring should extend a little above the top of the tube.)

In a piece of board, bore a hole large enough so that the tubing fits snugly into it. Support this wood by two blocks, as shown. Place a one-pound weight on the top, thus compressing the spring slightly. As the plant grows, it will press the vial upward against the spring.

Loosen the soil around the tube, so that the air and water can have access to the roots. Paste a piece of gummed paper on the outer tube. Each day, mark the height to which the inner bottle has been raised. When the plant can compress the spring no farther, remove the tube, spring, and vial and invert. Pour lead shot into the vial until the spring is compressed to the same point as it was by the plant (Fig. 3). The weight of the vial, plus the weight of the shot it contains, will be the force of the plant's growth.

If you now want to find out the pressure the plant can exert, measure the area of the cross section of the narrowest part of the stem (in square inches). Divide this into the force (in pounds) the plant exerted. This will give the pressure exerted by the plant in pounds per square inch. For example, in one case it was determined that the plant exerted a force of one pound. The diameter of the stem just below the cotyledons (the first leaves) was ⅛-inch. Thus:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{1 \text{ lb.}}{\pi (1/16)^2}$$
$$\text{Pressure} = 81.5 \text{ lbs./sq. in.}$$

As a result of such pressure, the stems of plants can exert considerable upward force, pushing aside stones and even cracking concrete.

This project illustrates the application of physics and mathematics to a project in biology. Measurement is a very important part of any science, and all too frequently people forget that the techniques of one science may be applied in another.

Slowing down protozoa

How can protozoa, especially the ciliated forms, be slowed down for close observation under a microscope? There are two methods you can use:

1. Moisten a small piece of lens tissue. Place it on a slide, and tear it apart with a pair of dissecting needles. Spread the fibers uniformly over the slide, and add a drop of concentrated protozoa culture. When the cover is placed on the slide, the protozoa will be trapped among the strands of lens tissue. However, cilia and the larger cirri may be damaged.

2. A far better method enables you to observe protozoa in slow motion. Prepare a solution by dissolving 5 grams of methyl cellulose in 40 ml. of water. Place one drop of this syrupy solution on the slide. Add one drop of protozoa culture, and cover with a cover glass. There are several advantages to using methyl cellulose: it is easily obtainable from chemical supply houses; its solution is transparent; and it does not change the osmotic pressure of the water surrounding the protozoa. By varying the amounts of methyl cellulose you can arrive at a concentration that enables you to observe the cilia of, say, a paramecium in slow motion. — THEODORE BENJAMIN

Edd Wall is one of the men who helps make better synthetics.

This is his own story of how he went

From chemistry set to chemical engineer

THE AUTHOR examines raw material from which Dynel fiber will be spun.

■ My formal introduction to science came when, as a boy of twelve, I received a chemistry set for Christmas. The chemicals in the set were most intriguing. However, I soon tired of the experiments because I knew in advance their results. So I began conducting my own experiments with the remaining chemicals. I remember how pleased I was when I got a color change or some other visible result. I really had no idea what I was making, but the adventure of it all kept me busy until I ran out of chemicals.

Then my parents gave me a microscope and equipment for making slides. Again I was overwhelmed, this time by the wonder of the world seen under a microscope. I drove my parents nearly batty asking questions. I collected insects, feathers, hair, and other specimens to make permanent slides.

I soon decided to become a scientist. This idea, however, was almost sidetracked after I completed a course in general science in the ninth grade. The course had no laboratory period, and it seemed to me that all we did was copy pictures from our text. The copies were to be bound into a notebook, which would be graded as the major part of the course. I got the idea that a scientist must be an artist. Since I wasn't much of an artist, I figured I probably wouldn't make a good scientist.

Nevertheless, I continued to take all the science and mathematics I could while attending Newton (Mississippi) High School. The course that dispelled my mistaken idea about science was chemistry. After completing the course, I was firmly convinced that I wanted to be a scientist, preferably a chemist or chemical engineer. I received a brochure from one of the state colleges outlining the different types of work that graduate chemical engineers did. I decided that the work suited me. This decision was reached without my ever having met a chemical engineer or having visited a chemical plant, since the area around Newton, where I lived, was primarily devoted to farming and dairying.

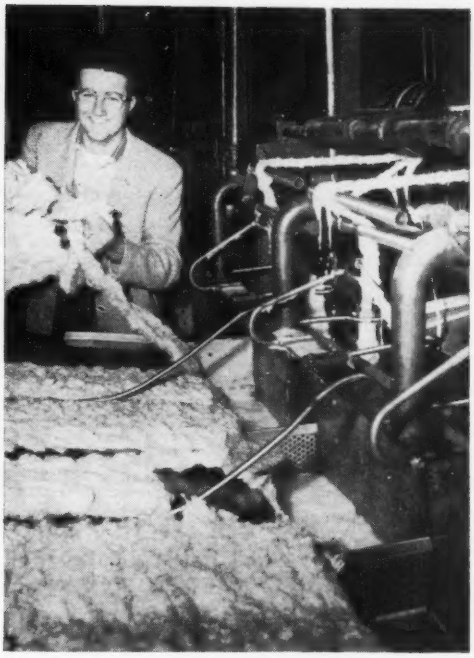
After graduating from high school, I attended a junior college near my home for two years. This college was recognized by the senior colleges in the state as offering the best preparatory engineering course of all the state's junior colleges. Looking back on those two years, I don't regret at all having gone to a junior college. The small classes gave me an opportunity to develop my scientific ability more thoroughly than I believe could have been possible in large classes.

My chemistry professor was an excellent teacher. His method of lecturing was one of asking questions. In fact, he asked questions and required answers of his students wherever he met them — in class, in the lab, or even out of class. From him, I learned a trait that has helped me considerably — the habit of studying by questioning myself. This makes me think clearly. If I can't answer a question immediately, then I don't know enough about the subject or my conception of it is wrong.

During college (as well as high school) I took as many courses in the humanities (history, literature, etc.) as I could. I wanted to develop a broad knowledge outside of the field of science. Also, I participated in musical, athletic, and other activities. In high school I had been vice-president of the senior class. I had participated in all high school sports and had been a member of our high school team that won the state baseball championship. In junior college I was active in the

— Photos from Union Carbide Corporation

BELTS OF TOW, each consisting of 10,000 continuous fibers, are inspected by Edd as they emerge from lubricating baths.



DRIED TOW is being fed into another lubricating bath, then will go through stretching tubes to line up its molecules.

band and chorus and was editor of the school yearbook one year. These non-science activities helped clear my brain after I had packed it full of technical knowledge in the science classes.

I received my first taste of practical chemical engineering after graduating from junior college. On the recommendation of the junior college business manager, I landed a summer job with Mississippi Chemical Corporation, a manufacturer of nitric acid, ammonia, and ammonia-based fertilizers. That summer was most rewarding, for I worked with and talked to practicing chemical engineers. I got a chance to see how a chemical plant operates and what problems a chemical engineer encounters.

My summer project was to design an experiment to determine the amount of ammonium nitrate (used in fertilizers) that was being lost via the plant sewer. The project required the use of many scientific principles and gave me an opportunity to talk with the non-technical plant personnel — chemical operators, maintenance men, laboratory technicians. I found that about two tons of nitrate were being lost each day. As a result, the company decided to take measures to recover it.

In the fall, I began my final two years of college at the University of Mississippi. Part of the university expenses were paid by an academic scholarship, which I received as a result of my high school and junior college work. (I had been valedictorian of my graduating classes in both high school and junior college. And in junior college I had received the freshman awards for chemistry and mathematics.)

Again I was fortunate to be in a small class where I could benefit from the experience of the instructors. The three chemical-engineering professors had among them over twenty-three years of practical experience with well-known industrial companies. The class and laboratory courses were designed to introduce the student to types of problems he might encounter in industry. We were not given a detailed instruction sheet for laboratory experiments. Rather, we were required to design our own experiments with the existing equipment, to determine what we wanted to find out in the experiments, to learn independently how to operate the equipment, to conduct the experiments, and to publish our results, conclusions, and recommendations. The class homework and tests were based on the honor system. We were allowed to work on the tests in our own rooms with any reference books that we needed.

The professors made every effort to prepare us for our future work in industry. The course was tough and time-consuming, but I'm glad now that it was, for the transition from college to industry was much easier than I had thought it would be. In our school work we were constantly writing reports and lecturing in class to explain special problems. In addition, the professors told us to respect the ideas and opinions of the people we worked with in industry and to do any job we were assigned with the same effort and enthusiasm. As one said, "Never think you are exempt from doing a dirty job because you are a chemical engineer. Do the job well without complaining, and your supervisor will find more important things for you to do next time." Over-all, I believe that this approach to education best prepared me for a chemical-engineering job.

Aside from actual school work, I was chairman of the student chapter of the American Institute of Chemical Engineers and a member of Gamma Sigma Epsilon, a national chemical scholastic fraternity. These activities enabled me to get some valuable experience as an administrative officer of an organization.

During the summer between my junior and senior years, I worked for Union Carbide Chemicals Company in the Dynel Production Unit of the com-

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Students preparing for a career in chemistry will be interested in the late Dr. Irving Langmuir's analysis of this field and its requirements. *Should You Be a Chemist?* is offered by the New York Life Insurance Company. Check No. 4213.

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pany's South Charleston (West Virginia) plant. I obtained this job on the recommendation of the head of the chemical engineering department at "Ole Miss." As you probably know, Dynel is a synthetic fiber that is woven into fabrics.

After two weeks of breaking-in, another engineer and I were assigned a project — to conduct an experimental production run using a new lubricant on Dynel thread. We had to plan the arrangement of equipment, calculate the amount of lubricant to be applied, conduct the run, collect data and lab samples, and write a report on the results. Our experiment showed that the new lubricant could be handled successfully on a production scale. It also showed that thread treated with the new lubricant could be processed more easily. The lubricant is now replacing the older one on the production line.

I also worked on various smaller projects. For example, I made a study of the baths through which Dynel fibers must go during processing. The purpose was to see whether a constant temperature was being maintained in each bath. As a result of the study, several hot spots were found in the baths and eliminated.

During my final college year, seniors were constantly being interviewed by companies interested in hiring chemical engineers. I was interviewed by several companies and received job offers from each. I chose Union Carbide chiefly because I had had such an enjoyable and enlightening summer experience. I knew the people I would work with and for, and had a good idea about the opportunities available to me. In each interview I had used Union Carbide as a standard and had compared other companies to it. For me, none approached the standard. I sincerely believe that my summer jobs enabled me to make a wiser and more permanent decision than I could have made if I had not worked. Also, I believe my experience helped me do a better and more mature job once I got into industry.

I was graduated from the university with Distinction honors (the second highest honors) and began work at Union Carbide's South Charleston plant in October, 1957. I was assigned to the Resins and Fibers Production Department under Mr. J. P. Ferrer. This department produces synthetic resins, the starting materials used in plastics and synthetic fibers. It also produces the actual synthetic fibers.

My first assignment was to prevent a dried resin from agglomerating — collecting into balls — when stored in bags. I worked on the project off and on for a year. The problem was most baffling until I cast aside prevailing theories and adopted a basic approach to determine the cause and effect of the problem. I was then able to prevent the agglomeration from occurring.

In general, my efforts were directed in three areas: (1) long-range planning for the basic improvement of production processes; (2) trouble-shooting for the immediate improvement of processes and product quality; and (3) experimenting on a plant scale with new products still in the development stage. This work required me to develop ideas — my own or others' — into safe, workable, and economical plans that could be adapted to plant operation. In developing these plans, I had to engage in small-scale experiments, estimate costs, and co-ordinate the plans with such groups as safety, research and development, shipping, and sales.

The developed idea was then submitted to management people for approval or disapproval. I learned that often the manner in which an idea is presented goes a long way toward selling it. Once an idea was approved, I had to see that it was carried through.

One of my early projects was to work up on a plant scale a lab-scale process for producing 100,000 pounds of potassium sorbate. The product is used to prevent or slow down mold formation on cheese, pickles, and other foods. In this project I had to be particularly concerned with product quality, since this is of utmost importance in a food product. Equipment had to be kept thoroughly clean, and strict habits of cleanliness had to be followed by workers.

Another project involved determining and correcting the cause of customer complaints about one of our vinyl resins. One customer wanted a whiter resin. I tried to whiten it by bleaching, but wasn't successful. We must continually experiment and plan in an effort to improve our products and the ways in which they are made.

So far my experience as a chemical engineer has been challenging and exciting — just as exciting, in fact, as was my childhood chemistry set. The rewards, both in money and in sheer satisfaction, more than justify the effort. What more can a man want from his job? — EDD WALL

On the light side

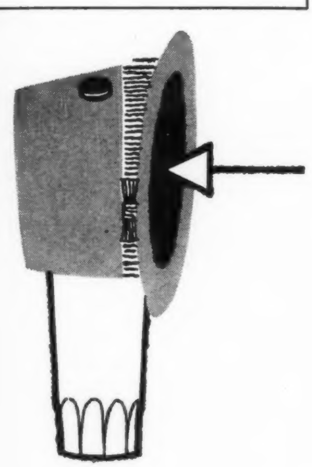
Brain teasers

Who's on first?

John, Charles, and Harvey are on the same baseball team. They have the positions of catcher, first baseman, and left fielder, but not necessarily in that order. The catcher is the youngest and is an only child. John is older than the first baseman and is married to Harvey's sister. What position does each man play?

Second tide

Most everyone knows that high tide is caused by the moon's gravitational pull on the earth's oceans. Curiously, at the same time there is a high tide on the side of the earth facing the moon, there is also a high tide on the opposite side of the earth. What causes this second tide?



Drawings by LoCurcio

Hat and penny trick

Turn a man's hat sideways, and set it on an empty drinking glass, as shown. Place a penny on the hat, making sure that the coin is directly above the glass. Challenge anyone to knock the hat away with his finger so that the penny will drop into the glass.

It looks as if it should be easy, but whenever someone tries it the penny flies across the room. Reason: when the side of the hat is struck, it causes the portion of the hat beneath the coin to spring upward, catapulting the penny.

After everyone gives up, you show how simple it is. The secret is to strike the *inside* of the hat with your finger at the point shown by the arrow. This eliminates the catapulting. Inertia keeps the coin from moving with the hat, and the coin will fall neatly into the glass.

Cube-root mystery

"Choose any number from 1 to 100," says the lightning-fast human calculator. "Cube it, and give me the result." (The cube of a number n is $n \times n \times n$.) After learning the result, he quickly tells you the original number. How does he do it?

The feat is an easy one if you take the trouble to memorize the following table of the cubes of 1 through 10.

1 — 1	6 — 216
2 — 8	7 — 343
3 — 27	8 — 512
4 — 64	9 — 729
5 — 125	10 — 1,000

Suppose someone calls out 250,047. The last digit is 7. A cube in the table that ends in 7 is 27. This tells you that the last digit of the cube root is 3.

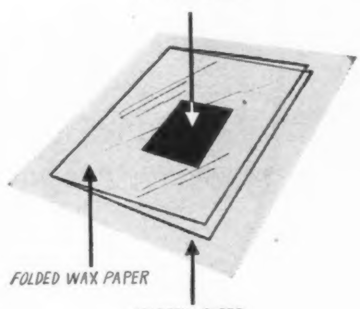
Next, discard the last three digits of the cube and consider what remains. In our example, the remaining figures are 250. In the table, 250 lies between the cubes of 6 and 7. The *lower* of the two cube roots — in this case, 6 — will be the first digit of the cube root we are seeking. The original number, therefore, is 63.

Color complements

An interesting physiological experiment, known as "Meyer's experiment," can be performed easily with a sheet of colored paper, a small square of gray cardboard, and a sheet of wax paper from a kitchen roll.

Place the cardboard square on the colored paper (a bright red or green works best). Then cover both paper and square with wax paper folded once, twice, or three times, depending on its thickness. The square, seen through the transparent paper, will appear strongly tinted with a color complementary to the color of the paper. That is, it will seem light green if red paper is used, pinkish if green paper is used.

The effect is closely related to the fact, familiar to all artists, that shadows of colored objects acquire a tint of the complementary color. A classic discussion of Meyer's experiment will be found in chapter 17 of William James's *Principles of Psychology*. — George Groth



Answers

WHO'S ON FIRST? The fact that John is older than the first baseman rules out the possibility that he is the first baseman or the catcher (because the catcher is the youngest). Therefore he must be the fielder. Harvey can't be the catcher (because he has a sister) or the fielder (because John is the fielder), so he must be the first baseman. This leaves the position of catcher for Charles.

SECOND TIDE: We usually think of the moon as revolving around the earth. Actually, both the moon and the earth revolve around a point within the earth. This point is their common center of gravity. It's as though the two bodies were attached by a rod whose pivot was their common center of gravity. As the earth swings around this point, its motion tends to throw the water on the opposite side of the earth outward. Thus the seas rise on this side.

Stranger than fiction

By Murray Morgan

They hunt the smallest game

Stalking unknown viruses in the Amazon jungle of Brazil, the Causeys add to man's knowledge of diseases and their transmission

CONCLUSION ■ The second new virus to be isolated by the Causeys came from a colony of Japanese immigrants on the Guamá River, a tributary of the Amazon, a few hours upstream from Belém. The colony can be reached only by water, and there, by launch, the Causeys took me one May morning.

Dr. Causey called for me at 5:30 A.M., and by six we were on the launch, hunched up in rickety deck chairs set on the bridge behind the captain. We pushed upstream, and soon we were on the broad, yellow-brown river of all travel books, the endless highway through the endless forest. The jungle to the left was in shadow and dark green, the jungle to the right in partial sunlight and bright green. It was a jungle of palm trees and rubber trees, with an occasional sumaumeira tree, the source of kapok, thrusting its smooth, oval crown above the others.

The Causeys talked of their life as a scientific team in Brazil. They had met at Johns Hopkins University, when Ottis returned to teach there after a five-year stint as a professor in Thailand. He left academic life in 1939 to work on malaria in Brazil; Calista followed him south a few months later. Since it is difficult for foreigners to wed in Brazil, they were married by proxy.

They have been in Brazil for eighteen years, working mostly in yellow-fever campaigns. Most of the war years they spent at Belém as part of the joint Brazilian-American effort to make the Amazon safer for workers bringing strategic material from the jungle. So they were no strangers to the problems they faced when they returned in March 1954 to hunt viruses.

The Causeys take lightly the fact that several of the known viruses they handle are killers and the unknown may well be just as deadly. Neither has ever been sick with one of their viruses.

"We just take care not to be bitten," said Mrs. Causey, quite seriously. "We try not to go where the mosquitoes are thickest any more than we absolutely have to. When we are in deep jungle we try not to work up perspirations—that attracts them. We use repellants, when we remember to. And we don't do what the workers do, which is to work so hard that when they sit down to rest they don't even notice what bites them."

She paused and added, "Of course, there are times when it is rather difficult to avoid being bitten. For instance, when you are going up a small stream in a canoe at twilight. Then you just hope. The odds are always in your favor on any given bite."

When they return to the States at some uncertain date in the distant future, the Causeys intend to raise stock on a ranch they have purchased in the hills of the Carolinas. There Ottis expects to test a theory which grew out of some unpleasant experiences he had at formal parties in Thailand.

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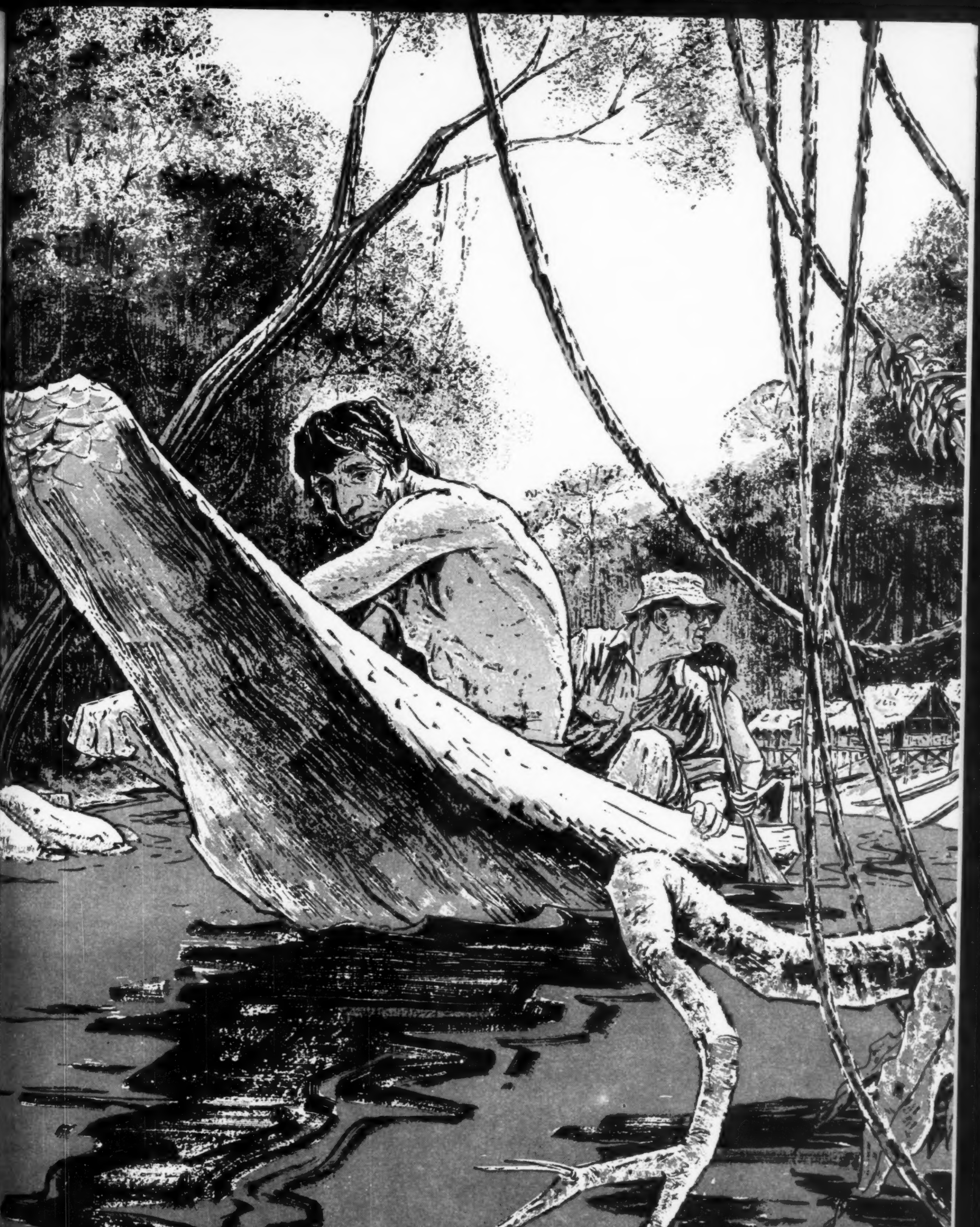

"I noticed," he said, "that whenever I had to wear black stockings the mosquitoes bit me terribly. It was so bad I had to wrap newspapers around my ankles under my socks. That set me to wondering if perhaps insects were attracted to black. I began to count the ticks on spotted cattle, and I found ten times as many on the dark patches as on the white.

"So my idea is to take Brahman cattle and cross them with Angus, but, instead of working for a black hybrid, to develop a white one. Then, in my white herd, I will have two or three black cattle. The idea is that these will attract the ticks. Since I will have heavily sprayed the black cattle with insecticides, they should lure most of the insect pests to their death. Anyway, it's worth a try. The country is beautiful."

Our launch paused opposite the pagoda-like headquarters building, which bore a sign, *Colonia do Guamá*. Dr. Causey called ashore to ask if there were any known fever cases along the river. A tall Japanese shouted back that some people were said to be sick at Tacojos, the town where the Brazilian land-clearing crews lived, a couple of miles up the Caraparu.

Since the tide was high, we went by launch.

Tacojos was dreary, a sad spread of board and batten houses standing in a muddy clearing. Some six hundred persons lived in the dirt-floored shanties. Others were in small camps nearer the scene of operations.

Several people complained of being sick, but their complaints seemed to be mere headaches. Dr. Causey fed them all aspirin and hurried on in search of more promising cases. He brightened perceptibly when he found a man hammock-bound with a high fever; but the patient turned out to have had the temperature for a week, which indicated an earlier presence of virus but also meant that probably the virus had passed on and that the blood would yield only antibodies. Just to make sure, they bled him.

As we started down the river from Tacojos, the Causeys said the Japanese, unlike the Brazilian land-clearing teams, were able to stay out of the deep jungle and avoid exposure to insect vectors. Four viruses had been isolated among the Brazilians and only one among the Japanese.

We left the Caraparu and turned up the Guamá. The launch stayed close to the bank, and as we passed the colonists' houses Dr. Causey again called ashore to ask if anyone was sick. No one was. Eventually we turned back toward Belém. We had not gone far when a black dugout shot out from the shore and cut across our bows. The paddler, a heavy-shouldered Japanese boy, tossed his paddle in the air and waved delightedly at us. The Causeys waved back.

"He's the one who gave us the virus," said Mrs. Causey. "He'd gone back into the forest for some reason and he got a virus."

"He went in to cut down a tree to make a dugout," said her husband. "He was working on the dugout when I came along. He had a temperature of thirty-eight point something-or-other [centigrade], and his head ached, he felt dizzy, he hurt all over but especially in his back — but there he was, working away on a dugout. A real Japanese, that one.

"When I came back here a month later to get convalescent serum he felt fine. Said the fever left him weak for a few days, but that he never let it keep him in bed.

"Turned out to be Guamá virus. It was the first time it was isolated in man, although we had found several strains previously in monkeys."

When the Causeys first started hunting virus, they planned to trap monkeys and check their blood to see what viral agents and antibodies were present. Dr. Causey was an old hand at monkey-trapping. While in central Brazil studying the movement of jungle yellow fever, he had enticed some twenty-four hundred monkeys into tilted boxes like those small boys use for capturing birds,* and he expected similar success with the Macaco prego monkeys (*Cebus apella*) on the Amazon.

On arrival in Belém, Dr. Causey set a series of boxes on the floor of the jungle, went back to the lab, and returned the next day to reap his reward of *Cebus*. No monks. Every box was ajar except for one that contained a young anteater.

A second trial and a third failed to bag even an anteater.

After discussing the monkey-trapping problem with Mrs. Causey and with local hunters, the doctor decided that there were so many pumas and other cats, as well as anacondas and lesser snakes, in the jungle near Belém that monkeys had learned never to come to the ground. Those that didn't learn didn't survive long enough to be trapped.

Pursuing his investigation, Dr. Causey heard that *Cebus* monkeys were often seen on the ground on the island of Maiandeua, off the mainland coast south of the Amazon. There he placed his traps and quickly filled them. From each of the monkeys he took back to Belém he drew blood which was sent to New York for analysis. He needed to know which viruses the monkeys had been exposed to. The antibodies would show that.

New York reported back that the Causeys' monks showed no traces of viruses. "It was a gift from the gods," Dr. Causey said later, "the weather gods. The prevailing winds make difficult the transfer of mosquitoes from the mainland in large numbers, and the monkeys were perfect hosts for any disease which might be lurking in the jungle."

The Causeys hung their monks in wide-mesh wire cages in the jungle. They were suspended fifteen to twenty feet from the ground, far enough up so that no puma could leap to them, far enough down so that the most enterprising snake could not get at them, but at a height convenient for mosquitoes. The sentinel monkeys were fed and watered daily and bled twice a week for mouse inoculation.

The first ten monkeys were posted in the Oriboca forest, and from the first bleeding seven days later two viruses were isolated from two of them. On the next bleeding, three days later, another virus was isolated from one of the same monkeys. These were identified in the New York laboratory as Venezuelan equine encephalomyelitis and two new viruses now designated as Oriboca and Marituba. By the time sentinel monkeys were withdrawn from the Oriboca forest ten months later, nineteen of the forty-four animals exposed had become infected with one or more viruses, yielding a total of twenty-seven viral agents.

When the yellow-fever outbreak was at its height, the Causeys stationed four other monkeys in the forest of Apeu to see if the yellow-fever virus existed there. Yellow fever was not found in the monkeys, but four other agents were obtained from three of them. A dozen sentinels posted in the Utinga watershed yielded a total of thirteen viral agents.

Besides their tests on sentinel monkeys, the Causeys have bled and searched for viral agents in a strange

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* The monkeys he captured in central Brazil he banded, then released. They were subsequently recaptured close to the spot where they were originally trapped. He also caught mosquitoes, colored them with gold leaf, and released them. Some traveled as much as eighteen kilometers in forty-eight hours. From this, Dr. Causey reasons that the migration of mosquitoes is more likely to spread disease than the movement of the monkey host.

Illustrations by William Bryant

ANCIENT, PATCHED-UP EQUIPMENT in Dr. Causey's lab underscores point that important discoveries can be made without modern apparatus.

assortment of animals, including horses, night monkeys, squirrel monkeys, juparas, miniature anteaters, two-toed sloths, three-toed sloths, opossums both woolly and brown-masked, spiny rats, water rats, bats, juritis, inambus, chickens, lizards, and chameleons.

They have also captured 53,623 arthropods for virus isolation. Most of these were taken with human bait — boys hired to sit in the forest and catch any mosquitoes or other insects that landed on them.

On my last day in Belém two other visitors descended upon the Causeys — Dr. Paul Weinbren of the Virus Research Institute in Africa and Dr. Jordi Casals of the central Rockefeller virus laboratory in New York.

They visited the laboratory and studied, with some wonder, the ancient equipment. The suction pump is improvised from an old crock. The centrifuge has been repaired with old auto parts. An ancient refrigerator looks more suited to cooling ginger ale than storing precious vials of serum. All electrical equipment in the building is dependent on the Belém power system, which in turn is dependent on a long chain of weak links. Neither of the two stand-by generators in the laboratory works consistently. Ottis Causey rose to the defense. "Oh, it is a bit antediluvian," he conceded, "but we like to believe that this is not altogether unfortunate. We receive visits from a number of students returning to their own countries after being trained in big schools up north, with their modern laboratories. Most Latin American countries don't have such laboratories, and the students tend to think they can't work in their native lands without all the latest gadgets and gimmicks. They watch us with our ancient methods and patched-up equipment, and they ask us, 'But can you do it that way?' And the answer of course is that the techniques we use here are pretty much those which led to the first great discoveries in the field. We're still doing it the hard way. We think this may encourage the students to work on virus even without the latest labor-saving devices. Still, I wouldn't mind a power plant we could depend upon."

We spent the last evening talking virus at the Causeys' house. At one point, Dr. Causey said to Dr. Casals, "Did I tell you that a tern was found on an island just east of here that had been banded by the U.S. Fish and Wildlife Service? We sent in the tag and got back word that the bird was banded in March, last year, in Massachusetts."

Casals traced a pattern on the tablecloth, then, looking up, said thoughtfully, "It could be coincidence, of course, but the path of migration of that bird would lie directly along the line of countries and of states, at home, which suffer periodic outbreaks of eastern equine encephalomyelitis. That's pretty quick theorizing, I'll admit, but you've shown there's a reservoir of the virus down here. And how about western encephalomyelitis? Doesn't it follow the path of western bird migrations down the west coast?"

"That's right."

"Most interesting," Dr. Casals went on, talking more to himself than to us. "And the spread of Japanese encephalomyelitis has definitely been shown to be the work of birds."

"Tagged birds have been traced to Africa as well as here," said Dr. Causey. "That could explain some other migrations."

"Food for thought," said Dr. Weinbren.

I mentioned that I had heard in Colombia that the Franco laboratory at Villavicencio was studying birds as a possible medium for the spread of yellow fever.

"An interesting field," said Dr. Casals, "and broader than you've indicated. The work here and elsewhere has shown that the arthropod-borne viruses with which we are concerned can be divided into several groups on the basis of serological interreactions." Catching my look of distress, he simplified it. "That is to say there are tests — serological tests — which we apply to the virus, and we can group the viruses by their reactions to these tests: Group A, Group B, Group C, and probably more groups as we get more viruses.

"Such groups could only mean that the viruses concerned react in certain ways to certain tests. But there is the possibility that viruses of a certain group have a group identity in their relationships to man and lower animals. Two viruses of a group introduced into an animal produce mutual interactions which result in responses that neither could produce by itself.

"That leads to a very important question, which is whether a human population that has been exposed to infection by a virus will show an increased resistance against invasion by another micro-organism of the same group. We don't know the answer for sure. But it has been found that persons who have had dengue, or been inoculated with sera from a person previously exposed to dengue, have some protection against yellow-fever virus. And this provides the logical basis for the notion that exposure to one member of a group could afford protection against others.

"This could be very important."

Neil Silver of Baltimore, Maryland, writes:

What is the color of the sun?

The sun is yellow. Though it sometimes appears red or almost white, the color change is really an effect of the earth's atmosphere. Stars, of which the sun is one, range in color from blue-white to yellow to red. A star's color depends on its surface temperature. Blue-white stars are the hottest (up to 80,000°F.); red stars, the coolest (about 4,000°F.). The sun's surface temperature (about 10,800°F.) makes it a yellow star. (A similar temperature-color relationship holds true for an iron bar that is heated until it glows: a white-hot iron bar is hotter than a red-hot one.) When a star's temperature is below 3,000°, it is not hot enough to glow and is almost invisible.

James Cranfill of Lansing, Illinois, writes:

Why does the leaning Tower of Pisa lean?

It leans because the ground under one side of its foundation has settled. The fault apparently stems from a combination of two construction errors. First, the Tower's foundation goes down not more than 10 feet, where the ground obviously isn't firm enough. Second, the weight of the Tower is not spread over a large enough area — the foundation's circumference is the same as the Tower's. The Tower's tilt is now such that the top is 15 feet from where it would be if the Tower were perpendicular. To insure that the Tower will go on leaning and not topple, the Italian government will use new techniques in an effort to solidify the ground under the building and attach it to the foundation.

Allan Walstad of Trenton, New Jersey, writes:

What makes a baseball curve when it is thrown?

The pitcher puts a spin on the ball, and the spin causes the ball to curve. How the spin does this is rather difficult to understand. First, you must forget the ball's movement in relation to the ground. Instead, think of the movement of the ball's *surface* in relation to the *air* next to it. This movement is determined by two factors: forward motion and spinning motion. When a pitcher throws a baseball with a spin, the spinning motion on one side is in the direction of the forward motion. So forward motion *plus* spinning motion determine the speed of that side in relation to the air. But on the other side, the spinning motion is in the opposite direction to the forward motion. Spinning motion therefore must be *subtracted* from forward motion. In other words, the speed of one side of the ball's surface in relation to the air is greater than the speed of the other side. Or, looking at it in another way, the air is flowing past one side of the ball faster than the other side. According to a physics principle called Bernoulli's Theorem, air pressure decreases when air speed increases. This means the air pressure on one side of the ball is greater than on the other side. As a result, the ball is pushed to one side — it curves.

Robert Fisher of Columbia City, Indiana, writes:

Is the tomato a fruit or a vegetable?

Botanically speaking, the tomato is a fruit, as are many of the edible plants we commonly call vegetables. In the strict botanical sense, the term fruit means ripened ovary — the sac that contains the plant's seeds. Botanists classify the tomato as a member of the berry family, since its seeds are buried in fleshy pulp. Legally and commercially, however, tomatoes are regarded as vegetables. The courts have declared the tomato a vegetable because it is eaten, cooked or raw, during the principal part of the meal.

Questions from readers will be answered here, as space permits. Send to: Question Box, Science World, 575 Madison Avenue, New York 22, N.Y.

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See also: American Optical Co., p. 7-T; Doerr Glass Co., p. 8-T

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TEACHER'S TOOLS

THE SCIENCE MATERIALS CENTER, a division of The Library of Science, has become highly important to the science instructor in less than a year. Here is a prime source from which the elementary, junior high, and secondary school science teacher can obtain low-cost and highly original scientific teaching tools. The Center was originated to fulfill these needs: to provide a *single* source of materials to satisfy youngsters' natural curiosity about science, to stimulate rewarding hobby activities, and to help teach — in a sound and enjoyable way — scientific principles, facts, and methods. As a part of its work, the Center manufactures and assembles kits and collections, many of which are of particular interest to schools. There are, for example, a Radiation Detection Kit, an Ultra-Violet Master Science Lab, a Basic Kit of Mathematics, and a Fractions Are Fun Game. Also, a Teacher's Demonstration Aneroid Barometer, Mr. Wizard's Experiments in Science, a Junior Scientist Magnetism Kit, and a Junior Scientist Static Electricity Kit. Best surprise of all is the modest price for these materials. Each kit contains an excellent manual of instructions, explanations, and other much-wanted data and information. Several sets of Toy Collections illustrating fundamental scientific principles run the gamut from the Imp Bottle Trick to Funny Putty (properties of materials). (*For a 121-page listing of these and other materials that could fan out into thousands of hours of sound science teaching, check No. 421A.*)

ALL MATTER is a game that provides a new method of stimulating interest in chemistry. Invented and produced for sale by Dr. M. R. Goran, it is a clever, fascinating device for making students thoroughly familiar with the elements. The game may be played by one or more persons. Symbols are matched with the names of the elements. (*Check No. 421B for complete description of "All-Matter" and quotations on quantity orders.*)

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Louis Pasteur, by Laura N. Wood. A great scientist uses the scientific method to perfect vaccines and the pasteurization process.

Road to Alaska, by Douglas Coe. Story of the "Alcan" road.

The Girl in the White Coat, by Helen Wells. Girls play vital role in medical technology, chemistry.

For a complete list of Messner books, write: Julian Messner, Inc., 8 West 40 Street, New York 18, N.Y.

Five tips
for teaching slow learners

(cont. from p. 2-T)

ognize with admiration every improvement he makes, however slight.

Suggest projects that even the slow learner can carry out successfully. Even a slow learner can enlarge a diagram from a textbook or from a magazine to make a teaching chart. And he can bring in an appropriate newspaper clipping for the class bulletin board, for which he should receive praise.

By making an effort to help the slow learner, you may be predisposing him to further learning. You may even be contributing toward making him a useful citizen. The good teacher, like the good doctor, is dedicated to carrying out his professional responsibility, even in the face of discouraging difficulties, and he doesn't give up easily.

— Zachariah Subarsky

How to do it

Introducing the concept of radioactivity — an approach

In the chemistry class or in the physics class there are more sophisticated ways of introducing the subject of radioactivity than that described below. Usually the approach is by way of the structure of the atom. The approach suggested is more suitable in general science classes or in biology classes preparing to study the uses of tracer elements in medicine, agriculture, and industry.

Begin by lighting a candle in the front of the room. Then ask the following questions and elicit from students the following answers.

Question: How can you explain the fact that you see the flame?

Answer: Energy in the form of photons radiates in all directions from the flame and reaches the eyes.

(Ask a student to come up to the front of the room and stand with his back to the burning candle.)

Question: Photons are still reaching the back of the student's neck and the backs of his ears. Then why does he not see the flame?

Answer: His skin cannot detect photons; only his *eyes* can.

(Have the student take his seat. Then place a sheet of tin or a panel of wood in front of the burning candle.)

Question: Why can't you see the flame *now*?

Answer: The photons are stopped by the solid material in front of the flame.

(Remove the opaque material and replace it with a pane of glass.)

Question: This glass is just as solid as the tin or wood. How do you explain the fact that you can see the flame through the glass?

Answer: Photons can pass through glass.

Question: In your experience, what other solid substances can photons penetrate?

Answer: Mica (thin sheets), cellophane, ice, etc.

Question: What generalization can we make about the penetration of solid substances by photons?

Answer: Photons can pass through some solid substances and not through others.

Question: Imagine a class of *blind* students in a room with a burning candle. Photons would be striking the students, but they would not be aware of the burning candle. If one of the blind students accidentally brought the back of his hand in contact with the flame, what might happen to his hand?

Answer: The student might receive a burn.

Now put out the candle, remove it, and in its place set up a source of atomic radiation. Give the following explanation:

This substance is giving off not photons but *other* radiations to which we are all blind. It does not even give off heat. But if you kept any part of your body near it long enough, you would receive a burn — not a flame-burn but a *radiation*-burn. If we can't see the radiations coming out of this substance, and if we can't feel them, smell them, or taste them, how do we know that the substance is giving out radiations at all?

At this point, bring out a Geiger counter and demonstrate it as a detecting instrument. Demonstrate the ability of the atomic radiation coming from your source to penetrate some solid substance (analogous to light passing through glass) and its inability to penetrate other substances.

This approach may consume an entire teaching period. But it will prove a good investment of time.

AO Reports on Teaching with the Microscope

Tranquilizers for Paramecium . . . or the care, feeding and observation of infusoria.

Generations of microscopists from Leeuwenhoek and Hooke down to present day biologists and medical workers have spent endless hours studying the ameba. You would think it had no further secrets left to fascinate present-day scientists. But not so! The ameba and its companion denizens of the primeval slime have come to us in unbroken genealogy from a period eons before the age of dinosauers . . . from the very beginning of creation itself. As a basic uni-cellular living organism, the ameba is more intensely studied today than ever before by scientists seeking the final elucidation of the life processes. Protozoa remain fascinating subject matter for student microscopists in the Biology classroom. With all this in mind, we offer the following generally well-known tips on the care, feeding and observation of the wee beasties.

MATERIALS:

Glass dish, approximately 8″ in diameter, 4″ deep (ordinary casserole pyrex dish); piece of plate glass; several petri dishes; timothy hay; pondweed; Methylene Blue; carmine or indigo powder; iodine; microscope slides; cover glasses; compound microscope; stereoscopic microscope.

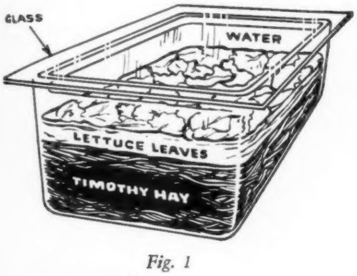


Fig. 1

HAY INFUSION:

Half fill 8″ dish with loosely packed timothy hay. Boil about two quarts of tap water for 5 minutes. Allow to cool and pour enough into dish to just cover hay. Add a 1 inch layer of the pondweed, Ceritophyllum. If out of season, or otherwise unobtainable, use unwashed lettuce leaves. Add more water to bring to within half-inch of top of dish. Cover with plate glass (see fig. 1). Keep in warm (normal room temperature), well lighted room . . . avoid strong, direct sunlight. Prepare several such cultures over a two-week interval. A brown, slightly odoriferous scum should appear. If scum disappears, or if whitish mold appears, discard culture. In a favorable culture, ameba will appear in 6 to 8 weeks. Additional protozoa will also be present, including Paramecium, Stentor, Euglena, and rotifers. Culture should thrive for 6 months or longer. Several such cultures will assure a plentiful supply of protozoa at all times during the school year. Occasionally add a malt tablet or few grains (pulverized) of rice as nutrient.

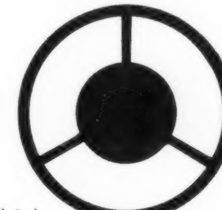
Fig. 2

OBSERVATION THROUGH STEREOSCOPIC MICROSCOPE:

Use a pipette to transfer some culture to petri dish . . . search the bottom of the culture dish for ameba, look along the sides where light is strongest for Euglena and look beneath decaying vegetable matter for Paramecium. Place petri dish on microscope stage. The stereoscopic microscope provides the unique advantages of three-dimensional magnification, long depth of focus and wide field of view to reveal, *in toto*, a teeming aquatic jungle of ameba, scooting paramecium, turgid rotifers and spinning ciliates (see fig. 2). If your school does not have a stereoscopic microscope, you may want information about the AO Spencer Cycloptic Microscope, Series 56F-1. Write to American Optical Company, Instrument Division, Dept. P252, Buffalo 15, N. Y. We'll be happy to send complete information at no obligation to you.

The stereoscopic microscope can also be used to establish "pedigree stock", or pure cultures. Simply hunt down the desired specimens with a wide mouth medicine dropper and innoculate a favorable culture medium such as Chalkley's fluid. Prepare Chalkley's fluid as follows:

NaCl	0.1gm
KCl	0.004gm
$CaCl_2$	0.006gm
Water (distilled)	1000cc



(*actual size*)

Fig. 3: Star diaphragm for dark field

OBSERVATIONS WITH THE COMPOUND MICROSCOPE:

DARK FIELD. It is difficult to see detail in live, unstained protozoa. Cutting down light intensity helps. If your microscopes have substage filter holders you can use star diaphragms to achieve dark field effect for better observation of general morphology. Make a star diaphragm out of stiff, black opaque cardboard. Use illustration (actual size) as pattern (fig. 3). Star diaphragm is slipped into filter holder and adjusted until best dark field effect is obtained.

STAINING. To see cilia, flagella and trichocysts, irrigate slide with very dilute iodine solution as follows: place drop of iodine at edge of cover glass on one side and place filter paper at edge of cover glass on opposite side. This will pull iodine under cover glass. To stain entire organism, proceed as follows: pipette some culture into Petri dish. Add Methylene Blue (not to be confused with Methyl Blue) until culture takes on definite blue tint. Observe drop of tinted culture under 10X and then 43X. Organisms will be stained blue for a short while and then gradually will return to normal.

FEEDING. To distinguish between food vacuole and macronucleus of ameba, add a pinch of finely pulverized Carmine or indigo powder to culture specimen on slide. Use cover glass and observe under 10X and 43X. Colored powder is rapidly ingested by ameba and accumulates in food vacuole. Powder grains can also be seen swirling into gullet of paramecium as they get caught in current set up by cilia.

Fig. 4: Photomicrograph of an ameba

SLOWING DOWN PROTOZOA. If the ameba is the tortoise of their aquatic jungle, the paramecium is the hare . . . they literally flash in and out of field of view. Adding a drop of water soluble methyl cellulose (or egg albumen) will slow paramecium and other ciliates and flagellates considerably. You can narcotize them motionless with a small drop of very dilute methyl alcohol. Once anesthetized, your students can attempt photomicrography with their do-it-yourself photomicrographic camera set-up described in an earlier AO Report on teaching with the microscope. If you are using stains, you might want them to experiment with color film.

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